National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

Canada

UNIVERSITY OF ALBERTA

Work Simulation: Gender Comparisons and Physiological Relationships in Healthy Subjects

BY

SHANIFF ESMAIL

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science.

DEPARTMENT OF OCCUPATIONAL THERAPY

Edmonton, Alberta
FALL 1993

National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-88311-1

Canada

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Shaniff Esmail

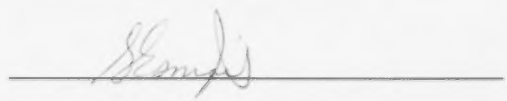
TITLE OF THESIS: Work Simulation: Gender Comparisons and Physiological Relationships in Healthy Subjects

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 1993

Permission is hereby granted to the University of Alberta to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as hereinbefore provided neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.



Shaniff Esmail
108 Kaskitayo Court
Edmonton, Alberta
T6J 3T3

DATE: 24 August, 1993

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Work Simulation: Gender Comparisons and Physiological Relationships in Healthy Subjects** in partial fulfilment of the requirements for the degree of Master of Science of Occupational Therapy.

Yagesh Bhambhani, Ph.D
(Supervisor)

Sharon Brintnell, MSc.
(Committee Member)

Jean Wessel, Ph.D
(Committee Member)

Date: 24 August, 1993

Abstract

The primary objectives of this study were: 1) to compare males and females, for the biomechanical and physiological responses during three upper extremity high intensity tasks performed on the Baltimore Therapeutic Equipment (BTE) work simulator, and 2) to examine the relationship between standardized tests of aerobic and anaerobic fitness and the biomechanical responses during the three work tasks in males and females. A total of 40 subjects, 20 males and 20 females volunteered their informed consent to complete 6 testing sessions. These included: 1) a familiarization session, 2) a peak VO_2 test on an arm crank arm ergometer, 3) a Wingate anaerobic power test on a arm ergometer, and 4-6) three work simulation tasks using the BTE to simulate turning a wheel (WT), pushing and pulling (PP), and overhead reach (OR). Anthropometric and peak aerobic and anaerobic performance were compared using T-tests. A two way ANOVA (sex by tasks) with repeated measures on the tasks was used to compare the differences between males and females. Pearson product-moment correlations were used to examine the relationship between the biomechanical response on the BTE for the three simulated work tasks and the various indices of peak aerobic and anaerobic performance. Results were considered significant at the 0.05 level. The three work simulation tasks were to have task and gender specific differences in

terms of evoking biomechanical and physiological responses at a perceived exertion of 15 on the Borg scale. The study results demonstrate that for certain tasks on the BTE, females would be under increased physiological stress to produce similar biomechanical output as compared to males. When correlating biomechanical performance with indices of aerobic and anaerobic fitness, no consistent relationships were observed among tasks. Where significant relationships were observed, they were found to be task and gender specific. This study has significant implications in terms of prescription of rehabilitation programs as well vocational screening. It is imperative that physical capacity testing should be specific to the type of employment the client is pursuing. In addition, gender differences must be accounted for to prevent discrimination and inappropriate job placement.

Key Words: Upper Body Work Simulation, Gender differences, Physiological responses

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to those individuals who have supported me during my graduate studies and in the completion of this work:

Dr. Yagesh Bhambhani for his continuous guidance and support; for his generosity in allowing me the use of his lab and equipment; and for always making himself available for any questions/discussions (even during his vacations).

Professor Sharon Brintnell and Dr. Jean Wessel for their participation and their input on the completion of this project.

The forty subjects who agreed to participate in this study - volunteering their time and their "vigorous effort."

The many individuals in the Department of Occupational Therapy at the University of Alberta for providing their assistance in various ways.

My wife Yashmina for her patience and continuous support over the past few years.

This study was funded by a grant to Dr. Yagesh Bhambhani from the Central Research Fund University of Alberta.

TABLE OF CONTENTS

CHAPTER		PAGE
I	**INTRODUCTION AND REVIEW OF LITERATURE**	1
	Work Capacity Testing of Upper Extremities	4
	Physiology of High Intensity Work	5
	Energy Consumption and Intensity of Effort	7
	Relationship of Peak Oxygen Uptake to Performance	8
	Physiological Gender Comparison	9
	Gender Differences in Aerobic Capacity	9
	Gender Differences in Anaerobic Capacity	10
	Wingate Power Test	11
	Reliability of the Wingate Power Test	11
	Factors Which may Influence Reproducibility	11
	Validity of the Wingate Power Test	14
	Use of Wingate Test as a Valid Indicator of Performance	15
	Wingate Power Test as an Indicator of Upper Body Work Capacity	17
	Rating of Perceived Exertion	18
	Upper Extremity Work Capacity Testing Using the Baltimore Therapeutic Equipment Work Simulator	21
	Summary	24
	Specific Aims	25

Instruments

Baltimore Therapeutic Equipment 26

Metabolic Measurement Cart 26

Percent Body Fat 27

Peak Oxygen Uptake Test 28

Wingate Power Test 28

References 30

II GENDER COMPARISONS FOR SIMULATED HIGH INTENSITY UPPER BODY WORK CAPACITY 47

Introduction 47

Methods

Subjects 51

Study Protocol 51

Calculation of Energy Expenditure 56

Statistical Analysis 57

Results

Subject Characteristics 57

Peak Physiological Responses 58

Work Performance During Three Work Simulation Tasks

Comparison Among Tasks 59

Gender Comparison for the Three Tasks 58

Physiological Responses During Three Work Simulation Tasks

Comparison Among Tasks 58

Gender Comparison for the Three Tasks 59

Discussion 60

Peak Physiological Responses 61
Task Specific Differences Within Gender 62
Gender Differences Between Tasks 64
Implications for Occupational Therapists . . . 68
Limitations of the Study 69
References 71

III RELATIONSHIP OF PEAK AEROBIC AND ANAEROBIC PERFORMANCE TO HIGH INTENSITY UPPER BODY WORK SIMULATION TASKS. 84
Introduction 84
Physiology of high intensity upper body work . 86
Peak Oxygen Uptake Relationship to Performance 86
Wingate Power Test 87
Rating of Perceived Exertion 88
Methods
Subjects 89
Study Protocol 89
Statistical Analysis 95
Results
Subject Characteristics 96
Peak Physiological Responses 96
Performance During Work Simulation Tasks . . . 97
Wheel-turn Task 98
Push-pull Task 98
Overhead-reach Task 98
Discussion 98
References 105

IV GENERAL DISCUSSION 121

Limitations 122

Implications for Occupational Therapy 125

References 129

V APPENDIX

Appendix A1 - Consent Form 133

Appendix A2 - Par - Q Form 135

Appendix B - Borg Scale 136

Appendix C - Summary Tables of Analyses of Variance 137

Appendix D - Bonferroni Adjustment 143

LIST OF TABLES

TABLE	DESCRIPTION	PAGE
I-1	Energy Expenditure and Work Classification	8
II-1	Characteristics of Subjects	79
II-2	Peak Physiological Responses During Arm Cranking in Males and Females	80
II-3	Comparisons of Simulated Work Performance of Three Tasks in Males and Females	81
II-4	Comparison of Steady State Physiological Responses During Three Work Simulation Tasks in Males and Females	82
II-5	Comparison of Energy Expenditure During Three Work Simulation Tasks in Males and Females	83
III-1	Characteristics of Subjects	115
III-2	Descriptive Statistics for Peak Aerobic and Anaerobic Performance	116

III-3 Comparisons of Simulated Work Performance of Three Tasks in Males and Females 117

III-4 Correlation Matrix for Physiological Variables and Performance on the BTE During the Wheel-Turn Task 118

III-5 Correlation Matrix for Physiological Variables and Performance on the BTE During the Push-Pull Task 119

III-6 Correlation Matrix for Physiological Variables and Performance on the BTE During the Overhead-Reach Task 120

CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

The assessment of job related disability is of great concern not only to health professionals working in the field of rehabilitation, but also to governmental institutions at all levels. The staggering cost of "occupational disability," defined by Yeater (1987) as "not being able to work at the original job due to work related injury," totalled 184 billion dollars in the United States, of this 114 billion covered the health care benefits, and approximately 70 billion financed wage replacement for time lost due to injury (Lepping,1990).

Currently, a number of physical work capacity tests which require extensive physical work are used to screen individuals seeking employment. These tests include measurement of the maximal aerobic power, muscle strength and endurance, flexibility and body composition (Davis & Dotson, 1986; Davis, Dotson & Laine Santa Maria, 1982; Dicarlo, Supp & Taylor, 1983; Knapik, Burse & Vogel, 1983; Knapik, Wright, Kowal & Vogel, 1980; Loeppky and Luft, 1989; Patton, Daniels and Vogel, 1980; Sharp, Harman, Vogel, Knapik & Legg, 1988; Shephard, 1987). While each of these tests provide specific information on the individuals physiological capabilities, none of them provide information pertaining to the individual's capacity to do high intensity work. Knowledge in this area is particularly important for

job specific screening or in the implementation of rehabilitation programs, as many occupations require short duration, high intensity efforts (Canadian Classification Dictionary of Occupations, 1986 & Dictionary of Occupational Titles, 1981). **High intensity effort**, for the purpose of this study, may be related to "heavy work load" which is defined as a task that is at an intensity which the person would be unable to continue for a period greater than six minutes without a rest break (Astrand and Rodahl, 1986).

Research in the area of physical work capacity testing is continuously expanding. A major reason for this increase has been the need to reduce costs of hiring inappropriate applicants for a specific type of work (Greenberg & Berger, 1983). Similar assessments may also be used as an alternative to mandatory retirement and gender discrimination (Davis & Dotson, 1987; Leon 1987; Sharkey, 1987; Shephard, 1990; Shephard, 1987). In certain occupations, specific tasks require high intensity effort such as restraining a resisting suspect in police work (Greenberg & Berger, 1983), or the many tasks associated with fire fighting (Davis, Dotson, & Santa Maria, 1982). These two occupations are examples of areas where it is especially imperative to have a valid assessment tool to assess the job applicant's ability to do high intensity work at the standards required so as to ensure the individual's safety.

Fitness assessments are regularly carried out as part of the above mentioned physical capacity evaluations for job screening or as part of rehabilitation programs. Generally, actual field performance test results are accepted more readily than the usual laboratory fitness tests (Rodgers, 1988; Shephard, 1990). Occupational therapists are well suited to design and implement such physical capacity evaluations (which are more closely related to actual work tasks) due to their training in task analysis and a philosophical base which requires the use of activity in work related evaluations (Lloyd & Fiqir, 1990; Matheson, Ogden, Violette, & Shultz, 1985). Through the use of activity, the occupational therapist can fulfil the role of a work evaluator which includes, performing work orientated treatment, job analysis, work tolerance screening, work capacity evaluation, and work hardening (Holmes, 1985).

A method often used by occupational therapists as part of physical capacity testing for both vocational screening and rehabilitation purposes is work simulation (Matheson, Ogden, Violette, & Shultz, 1985; Ogden-Niemeyer & Jacobs, 1989). Through work simulation, the therapist can reproduce actual job tasks as closely as possible. This will often involve the use of tools, equipment, material, work environment, and so forth. Advances in technology and the need for measurable objective data and increased versatility in terms of uses has led to the development of electronic

work simulators (Ogden-Niemeyer & Jacobs, 1988). One of these is the Baltimore Therapeutic Equipment (BTE).

When developing job screening test or rehabilitation programs, the occupational therapist must take into consideration any gender differences or lack of, to prevent gender discrimination and inappropriate job placement. In the past job screening was done by separating those individuals who could perform the job from those who could not. This led to informal groupings of traditional male and female jobs with little crossover until legislation enacted in the early 1970's made it illegal to use gender as a selection tool for employment (Rodgers, 1988, pg. 223). Shephard, (1990) reports that although legislation requires equal treatment, it does not prevent employers from practising differential treatment if they can demonstrate differences in gender that would prevent a worker from performing certain duties.

Researchers have tried to develop models to either predict performance or identify variables as possible predictors of work capacity. This may be possible through a better understanding of gender differences and the relationship between aerobic/anaerobic indices and high intensity upper body work simulation.

Work Capacity Testing of the Upper Extremities:

In the past, numerous work capacity assessments for

lower body exercise were done and the results used to predict upper body capacity (Sawka, 1986). However, Sawka in a review of literature, summarized that power output, heart rate, and oxygen uptake are all different for arm crank exercise as compared to leg exercise (1986). He also found arm crank exercise to be less efficient than leg cycle exercise and concluded from the various studies that physiological responses would vary greatly between the two exercise modes. Specifically, the maximum oxygen uptake (VO_2 max) and maximum heart rate for arm work are approximately 70% of and 90 to 93% of the respective values observed during leg work (Sawka 1986). In addition, most manual material handling tasks require the use of the upper extremities (Armstrong & Silverberg, 1987; Chaffin & Anderson, 1984). Therefore, it has been suggested that for the most relevant results, testing should involve the specific muscle groups involved in the activity (Bouchard, Taylor, Simoneau & Dulac, 1991; Sawka, 1986).

Physiology of High Intensity Work:

A steady state is defined as "the oxygen uptake which corresponds to the demands of the tissues (Astrand & Rodahl, 1986, pg. 299). Such a situation may be achieved in the occupational setting depending on the nature of job. An example of this may be an assembly line activity where the workers have to perform the same task repeatedly. If

workers achieve a steady state during a work situation, oxygen consumption equals the needs of the tissues, and "consequently, there is no accumulation of lactic acid in the body. Heart rate, cardiac output, and pulmonary ventilation have attained fairly constant levels (Astrand & Rodahl, 1986, pg. 299)." It was also found that in light exercise, energy output during the first minutes of exercise is delivered aerobically, however, during heavier, more intense exercise, anaerobic processes must supply part of the energy (Astrand & Rodahl, 1986). "The heavier the workload, the more important is the anaerobic contribution." (pg. 295).

Blood lactate concentration increases significantly with the intensity during both upper and lower body work. Generally, it has been found that lactate concentrations are lower during arm work as compared to leg work during maximal exercise. This may be attributed to the greater muscle mass involved in the lower extremities. However, greater blood lactate concentrations were found for arm crank exercise when comparing the two modes of exercise at a given submaximal power and oxygen uptake. This was probably due to differences in relative intensity. Anaerobic power and capacity were also found to be lower during upper extremity work as compared to lower extremity (Sawka, 1986).

Energy Consumption and Intensity of Effort:

Work intensity has been categorized as light, moderate and heavy through the measurement of oxygen consumption (Brown & Crowden, 1963; Shephard, 1987). These work intensities are also commonly described in terms of METS where "a MET is defined as a multiple of the resting metabolic rate. Thus 1 MET is equivalent to the resting oxygen consumption" which is equal to 3.5 $ml/kg/min^{-1}$ (McArdle, Katch & Katch, 1991). Intensity and duration are two important factors in determining work intensity. However, two individuals working at a similar intensity and duration may perceive the tasks differently. One may see it as "hard" and the other as "light" work. This may be due to the differences in the relative intensity at which they are working, (ie. when the oxygen consumption is expressed as a % of VO_2 max). For example, person "A" working at a moderate level (Table 1) whose VO_2 max is 50 ml/kg/min, is compared to person "B" who is also working at a moderate level but whose VO_2 max is only 35ml/kg/min; Person "A" is working at 30-45% of his VO_2 max while person "B" is working at 44-65% of his VO_2 max. Hence, person "A" would fall into the safe working maximum of approximately 40% of VO_2 max set by Shephard (1987) while person "B" would be over the recommended limit.

Table 1: Energy Expenditure and Work Classification

LEVEL	ENERGY - EXPENDITURE	
MEN	ml/kg/min	METS
LIGHT	6.1 - 15.2	1.6 - 3.9
MODERATE	15.3 - 22.9	4.0 - 5.9
HEAVY	23.0 - 30.6	6.0 - 7.9
LEVEL	ENERGY - EXPENDITURE	
WOMEN	ml/kg/min	METS
LIGHT	5.4 - 12.5	1.2 - 2.7
MODERATE	12.6 - 19.8	2.8 - 4.3
HEAVY	19.9 - 27.1	4.4 - 5.9

Relationship of Peak Oxygen Uptake to Performance:

Peak VO_2 has been shown to be significantly related to endurance performance during strenuous exercise (Astrand & Rodahl, 1986; McArdle, Katch, & Katch, 1991). Sharp, Harman, Vogel, Knapik, & Legg (1988) compared peck VO_2 for a repetitive lifting exercise to peak VO_2 testing for treadmill, leg cycling and arm cranking. All three were found to be significantly related to the repeated lifting task. Correlations for the treadmill, cycling and arm cranking modes were 0.91, 0.83 and 0.73 respectively. The correlations between treadmill VO_2 max and lifting VO_2 max was highest probably because both activities were weight bearing. To assess lifting ability, they found that task specific VO_2 would be most valid. White & Johnson (1991) evaluated the predictive power of physiological tests in categorizing alpine skiers into three levels: international,

national and regional which was determined through past performance. They found none of the peak VO_2 indices exhibited discriminatory power. This may be due to decreased need for endurance type of exercise in alpine skiing. Anaerobic capacity on the other hand was found to have discriminator power. It may be suggested that peak VO_2 is related to endurance performance. Whether it is also related to work capacity in the occupational setting needs to be addressed.

Physiological Gender Comparison:

Through traditional fitness measures, gender differences have already been established . There appears to be no significant difference between gender before puberty but, thereafter, males tend to have greater muscle mass, strength, respiratory function, maximal oxygen uptake, body size and cardiac output, and lower percent body fat than females (Astrand & Rodahl, 1986; McArdle, Katch & Katch, 1991).

Gender Differences in Aerobic Capacity :

After puberty, a woman's peak VO_2 has been reported to be on average 65 to 75 percent of males of the same age group (Astrand and Rodahl 1986). The gender differences have been attributed primarily to differences in body composition and haemoglobin content. Women in general have

greater body fat and 10 to 14% less haemoglobin (McArdle et al., 1991). Hutchinson, Cureton, Outz, & Wilson (1991) compared males and females using lean body mass (LBM), haemoglobin concentration and cardiac size. They concluded that the majority (68.3 %) of gender differences were attributed to cardiac size which also reflects the overall smaller dimensions of women (1991).

Gender Differences in Anaerobic Capacity :

Several researchers have examined gender differences when looking at anaerobic power and capacity. Maud and Schultz (1986) compared anaerobic test performance corrected for body weight and lean body mass between young active female and male subjects. Ben Ari, Inbar, & Bar-Or (1978) conducted a similar study using middle aged subjects, and Debryyn, Provost, and Sturbois (1984) used physical education students. All these investigators found overall male anaerobic performance were significant higher than females ranging from 30.5% to 66.5% for absolute values. However, after correcting for body weight and using lean body mass, no significant difference was found between males and females. It should be noted that for all the above studies, workload was not equal, women worked at a lower resistance than men.

Maud and Schultz (1986) did find a significant gender difference using other anaerobic testing protocol such as

the Margaria Kalamen and Lewis protocol. Both use body weight for power computations, and therefore, results relative to body weight could not be reported and only absolute values were used. The most significant variable found to account for part of the gender differences was body fat. Women in general were found to have 10% more body fat.

Wingate Power Test:

The Wingate anaerobic test was developed in Israel at the Wingate Institute for Physical Education in the mid 1970's. It is a supramaximal thirty second test which assesses anaerobic performance and is designed to quantify the amount of power that can be generated during exercise on an arm or leg cycle ergometer (Bar-Or, 1987; Patton, Murphy & Frederich, 1985; Watson & Sargeant, 1986). The Wingate Power Test's primary purpose has been to standardize the assessment of anaerobic work performance with the upper and lower extremities during high intensity exercise (Bar-Or, 1987). The Wingate test is easy to administer in both laboratory and field testing situations and, hence, has become a common method for assessing anaerobic power and capacity (Nebelsick-Gullett, Housh, Johnson, & Bauge, 1988).

Reliability of the Wingate Power Test:

The Wingate Power Test has been shown to be highly reliable, with test-retest correlations ranging between .89

and .98 for both arm and leg modes. The reliability tends to be higher for mean power than for peak power, (both measured over 30 seconds). This is probably due to the relatively higher error in the measurement of peak power. These figures were based on a wide range of subject groups from children to the elderly, and from normal subjects to subjects with some form of illness or disability (ie. COPD and neuromuscular disease). Sample size ranged from nine to 38 subjects in eight studies with the above population (Bar-Or, 1987).

Factors Which May Influence Reproducibility:

Bar-Or (1989) conducted a review of studies on factors which may influence reproducibility of the Wingate Test. These included climatic conditions, hydration, motivation, and effects of a warm-up. A summary of his review is as follows:

Dotan and Bar-Or in 1980 conducted an experiment where subjects performed the Wingate Test in different temperatures and varying humidity. It was found that high temperatures and humidity do not effect the reproducibility of the test. However, no research was done with regards to cold temperature. (Bar-Or, 1987).

Jacobs in 1980, as reviewed by Bar-Or, conducted a study where subjects were tested at three levels of hypohydration corresponding to 2%, 4%, and 5% of body

weight. No significant difference was found between the levels and Wingate results (1987).

Geron and Inbar in 1980 conducted Wingate testing with seven different types of motivation. These included audience, competition among individual subjects, competition among groups, punishment, reward, group association and social responsibility. Results indicated that motivation based on cognitive information has little or no effect on performance, while motivation based on emotional factors such as punishment, may improve performance. These results are stated to be limited to active, non-athletic, young adults. (Bar-Or, 1987).

As well, in 1975, Inbar and Bar-Or conducted a study where participants performed a test with and without a 15 minute warm-up. Warm-up subjects performed 7% higher on mean power and the same on peak power. Although the results of the study were found to be consistent and highly significant, the conclusions drawn from this study are limited. This is due to the use of a homogeneous sample (young boys). It was concluded that more data was required to determine optimal warm-up periods. (Bar-Or, 1987).

In conclusion the Wingate Power Test does not appear to be affected by heat, humidity, or hydration. However, a warm-up may improve mean power results and motivation factors must be considered (Bar-Or, 1987).

Validity of the Wingate Power Test:

Is the Wingate power test really a valid measure of anaerobic performance? The usual method of determining validity of a test is to measure it against a gold standard (Kerlinger 1973), however, this is not always practically possible. There are several physiological and histological variables that reflect anaerobic performance but none are considered standards (Bar-Or, 1987). Hence, researchers decided to compare the Wingate test to several different methods of assessing anaerobic performance.

Firstly Bar-Or, (1987) compared anaerobic performance in the field. Wingate test scores were correlated with performance in sporting events which required high intensity and short duration. Events such as sprinting, short distance swimming, short term ice skating task, and the vertical jump were examined. The second method was to compare the Wingate test to sports specialities not specifically categorized as high intensity short duration, such as sprint and long distance running. The final method of comparison used two laboratory performance tasks (the Margaria Step-Running Test and the Thorstensson 30 Second Isokinetic Knee Extension Test) to examine physiological measures. These measures included maximal oxygen debt, maximal blood lactate and muscle fibre types. "While none of these experiments can be considered the definitive validation study, their cumulative message is that the

Wingate anaerobic test is performed predominantly with anaerobic energy sources and that it taxes in a major way the anaerobic energy pathways." (Bar-Or, 1987, pg. 394).

Use of Wingate Test as a Valid Indicator of Athletic Performance:

The Wingate power test has primarily been used as an indicator of athletic performance. Subjects who performed well on the Wingate test were shown to do similarly well in their specific high intensity, short duration athletic event. For example, individuals who had high power outputs during the Wingate arm cycling test also performed well in short duration swimming events such as the 100 metre or 200 metre events (Vandevalle, Peres, Sourabee, Stouvenel, & Monod, 1989). Similar results were found in a variety of competitive level sports where high intensity efforts in terms of speed were required. These included race events such as speed skating (Van Ingen Schenau & de Groot, 1983; Van Ingen Schenau, de Koning, & de Groot, 1990; Van Ingen Schenau, de Boer, Geysel, & de Groot, 1988), sprint and distance running (Thorland, Johnson, Cisar, Housh, & Tharp, 1987; Mayers & Gutin, 1979; Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985; Priest and Hagan, 1984), cycling (Craig, Pyke, & Norton, 1989), rowing (Bell, Petersen, Quinney, & Wenger, 1989), and wheelchair track (Coutts & Stogryn, 1987). These results were also found in

professional and semi-professional athletes such as Hockey players (Montgomery, 1988), Bandy players (Hakkinen & Sinnemaki, 1990), Olympic athletes (Prampero, Limas, & Sassi, 1970), Judoists (Thomas, Cox, Legal, Verdi, & Smith, 1989), and persons described as athletes (Komi, Rusko, Vos, & Vihko, 1977).

Bar-Or concluded that although many researchers have used the Wingate test as a predictor of athletic performance, it is difficult to compare these results due to varying protocols, level of athletic efficiency, and ages (1987). He suggested that a more valid comparison would be to conduct testing in the same laboratory under ideal conditions. A similar study as prescribed by Bar-Or was conducted by Tharp et al. in 1985. Their study compared long distance and sprint runners and found that the subjects that excelled at short distance, high intensity sports scored higher on the Wingate power test. In contrast, Taulan as reported by Bar-Or (1987), found no significant difference between sprint and long distance runners in similar testing conditions.

A common factor found in all the above studies was the link between high intensity, short duration effort with high anaerobic power. Although sporting events described in the studies cited can not be directly compared to occupations requiring high intensity effort, it may be possible that the Wingate test could be a valid indicator of performance in

the occupational environment.

Wingate Power Test as an Indicator of Upper Body Work Capacity:

No studies have specifically focused on using the Wingate Power Test as a predictor of upper body work capacity or as a form of physical capacity testing for occupational performance. Nebelsick-Gullett, Housh, Johnson & Bauge (1988) did address some aspects of work capacity testing using the Wingate Power Test. The purpose of their study was to compare anaerobic capacity to anaerobic work capacity. Anaerobic capacity was determined by the total amount of work performed during the traditional 30 second Wingate Power Test, while anaerobic work capacity was obtained by having subjects perform three bouts of varying resistance lower body cycle work tasks to exhaustion. Study results demonstrated that anaerobic capacity and anaerobic work capacity were significantly related (r=.74). Nebelsick-Gullett et al. (1988), sited Inbar, (1976) and Stevens and Wilson (1986) who reported that 13 to 44% of the total energy requirements for the Wingate power test are from aerobic contributions. In addition it has been suggested that 30 seconds is not sufficient to determine anaerobic capacity Katch et al. (1977) as sited by Nebelsick-Gullett et al. (1988). Therefore the researchers reported that the study results may be confounded due to the

inability of the Wingate Power Test to fully define the subjects' anaerobic capacity.

The study, described is unlike the proposed study, because Nebelsick-Gullett et al. (1988) used lower extremity bicycle work instead of actual or simulated occupational work. Also, the aim of the proposed study is to relate Wingate Power Test performance to upper body work capacity and not to anaerobic capacity (although these may be related). However, the methodology used by Nebelsick-Gullett et al. (1988), of comparing Wingate Test results to work capacity performance is similar to the methodology of the proposed study. As this research shows a relationship between work performance and Wingate performance it, therefore, sets the stage for the proposed Wingate study.

Rating of Perceived Exertion:

The rating of perceived exertion scale developed by Gunnar Borg in 1970 (Pandolf, 1983) is an ordinal scale which subjectively estimates an individual's level of exertion during a physical task (Borg and Noble 1974) (Appendix B). This rating scale has been found to directly correspond to relative exercise levels and integrates messages from muscles, joints, cardiovascular and respiratory function as well as from the central nervous system. This 15 point scale ranges from 6 to 20 where the odd numbers on the scale are accompanied by verbal

descriptions ranging from 7 = very, very, light; 9 = very light; 11 = light; 13 = somewhat hard; 15 = hard; 17 = very hard; 19 = very, very, hard (Pandolf, 1983). The Borg scale is one of the most frequently used scales for measuring the degree of perceived exertion during physical work (Gamberale, 1985).

Studies conducted by Borg and Noble (1974) demonstrated a validity coefficient of .91 comparing the rating of perceived exertion and heart rate. Other studies reviewed by Pandolf (1983), comparing heart rate and peak VO_2 with the Borg scale, where each variable was kept constant experimentally, RPE was found to be higher for arm work as compared to leg work. However, the RPE was found to be the same for the two modes when looking at identical lactate concentration. This may be the factor which influences the increased perception rather than an increase in VO_2. Similar relationships were also found during continuous (C) and intermittent (I) exercise between the Borg scale and other different physiological measures such as blood lactate ($r=0.77$ for C; $r=0.63$ for I), VO_2 ($r=0.97$ for C; $r=0.92$ for I) respiration rate ($r=0.67$ for C; $r=-0.39$ for I) and ventilation ($r=0.94$ for C; $r=0.90$ for I) (Noble, Borg, Jacobs, Ceci & Kaiser, 1983; Pandolf, 1983; Skinner, Hustsler, Bergsteinova & Buskirk, 1973; Stanford, 1976). Ceci & Hassmen (1991) & Smutock (1980) also found that during higher intensity self regulated exercise (RPE of 11

or higher), physiological measures were highly reliable.

In terms of gender differences, Nobel (1982) reported no significant difference in RPE when compared to percent VO_2. Absolute differences of RPE response between gender were found to be related to differences in aerobic capacity.

A relationship has also been established between anaerobic threshold and the rating scale, where subjects' were found to perceive an exercise intensity equal to the anaerobic threshold as 13 (somewhat hard) (Purvis & Cureton, 1981). In addition, Patton, Morgan and Vogel (1977) found in a study examining high intensity, absolute physical exertion that "perception of the intensity of absolute work does not differ in groups differing in their level of fitness when studied cross-sectionally." (pg. 107). These results suggest that the Borg scale can be used as a measure of exertion in determining a consistent high intensity level for the study.

The use of the Borg scale is expanding in clinical settings and may have important applications in the occupational setting (Noble, 1982). The RPE may be used relative to metabolic demands at higher workloads and could be used to regulate intensity of effort during vigorous effort (Dunbar et al, 1992; Eston et al, 1987). In addition, RPE responses were found to be highly reproducible during continuous and interval work as well as at different work intensities (Stanford, 1976). A review of studies

demonstrates the Borg scale to be a valid and reliable tool when measuring perceived exertion during work.

Upper Extremity Work Capacity Testing Using the Baltimore Therapeutic Equipment Work Simulator:

The Baltimore Therapeutic Equipment work simulator (BTE) was developed by Engalitcheff Jr. and Curtis in 1979. The primary purpose of this instrument was for rehabilitation and evaluation of the upper extremities (Pendergraft, Cooper, and Clark, 1990). The BTE is designed to simulate a wide variety of movements with its 21 attachments. Measurement can be in both static or dynamic modes (Curtis & Engalitcheff, 1981; Powell et al., 1991). The primary advantage of using the BTE as compared to actual work tasks is that it allows for measurement of objective data. These include resistance, distance, time and specifically work done and power output (Curtis & Engalitcheff, 1981; Pendergraft et al, 1990; Powell et al, 1991). Such objective measurements would be difficult to obtain except through indirect methods such as heart rate and oxygen consumption. (Kennedy & Bhambhani, 1991).

Due to the limited research and the use of the BTE primarily in the clinical setting, very little information is available in terms of normative data. Although studies have been conducted on the BTE examining biomechanical responses, they have primarily focused on hand grip and

wrist flexion strength and power (Anderson, Chanoski, Devan, McMahon, Whelan, 1990; Berlin & Vermette, 1985; King & Berryhill, 1988; Trossman, Suleski, & Li, 1990). For test measures test re-test reliability was established (Anderson et al., 1990; McClure & Flowers, 1992; & Trossman et al.,1990). In addition, King and Berryhill (1988) were able to establish criterion validity when they compared BTE results with a Jamar dynamometer which has traditionally been used to measure grip strength. In terms of gender comparisons, Berlin and Vermette (1985) used the BTE to compare grip and wrist flexion between males and females. Overall, the mean scores for males were approximately 42-57% greater than for females. This study was limited in that it only looked at maximal biomechanical performance and not at repetitive work performance. As well it did not measure any physiological responses.

Kennedy and Bhambhani (1991) used physiological measures to assess test-retest reliability and establish criterion validity on the BTE. In this study, healthy male subjects were asked to perform actual work tasks each graded as light, medium, and heavy, while oxygen consumption (a measure of energy expenditure) and heart rate was measured. These were compared to measurements obtained during simulated tasks performed on the work simulator. Test-retest reliability was shown to be significant. Criterion validity was demonstrated during the light intensity tasks.

However, subjects were observed to underestimate the work intensity on the BTE at the medium and heavy levels. Which was observed through lower HR and oxygen uptake during the BTE tasks as opposed to the actual work tasks.

Wilke, Sheldahl, Dougherty, Levardoski and Tristani (1993) compared energy expenditure responses of several tasks performed on the BTE to similar tasks performed at work stations using actual tools and equipment, in men with coronary artery disease. Overall they found a tendency for the metabolic responses on the BTE to be lower than that of actual activities. RPE was also taken at the completion of the all tasks and no significant differences were noted for a majority of tasks. A factor that may have lowered the energy expenditure requirements for some of the activities on the BTE compared to the actual work tasks, was thought to be the inability of the BTE to duplicate the multiple integrated components and total body movements of actual work tasks.

No research is presently available on the relationship between high intensity work on the BTE and physiological fitness parameters such as aerobic and anaerobic power and capacity. Establishment of these relationships will clarify the importance of these traditional fitness measures and simulated work performance. This information will be of immense benefit to occupational therapists involved in work evaluation.

SUMMARY:

Physical capacity testing is a crucial component of vocational screening for individuals who have suffered an injury or who are planning to work in an area that requires heavy physical exertion. A review of literature indicates that there is a lack of information pertaining to the role of physical work capacity testing as it relates to occupational performance, particularly when the tasks are performed with the upper extremity. Evaluators, due to limited information and testing methods, have used lower body measures to predict upper body work. This method, as reviewed above, has several limitations.

It has been demonstrated that traditional physical capacity testing omits high intensity work which has been shown to be physiologically different from low intensity work. Through the use of the Borg Scale, a valid indicator of RPE during work tasks, a specific RPE can be achieved while performing a simulated work task on the BTE. By having a person do such tasks, objective measures of work capacity can be made. The work capacity results from this testing can be used to examine gender differences, and correlated with indices of aerobic and anaerobic fitness. Presently peak VO_2 testing is part of the protocol for physical capacity tests. The Wingate Power Test has been shown to be a valid and reliable tool in the assessment of athletic performance requiring short duration and high

intensity effort. If the work capacity results on the BTE and the results on the Wingate power test are shown to be significantly related, then they may also be included in physical capacity test battery.

SPECIFIC AIMS:

The objectives of the study were as follows:

1) to compare the biomechanical and physiological responses in males and females during three upper extremity high intensity tasks performed on a work simulator (BTE) at a rating of perceived exertion (RPE) of 15 (hard).

2) to examine the relationship between standardized tests of aerobic and anaerobic fitness and three high intensity tasks on a work simulator in males and females.

INSTRUMENTS

Baltimore Therapeutic Equipment:

The Baltimore Therapeutic Equipment (BTE) as described in the review of literature will be used to simulate three different work capacity tasks. These include: tool #131 (turning a wheel), which simulates opening a valve and turning a steering wheel; tool #171 (a push-pull activity), which simulates push-pulling an object such as a mop or heavy tools; and tool #181 (overhead-reach), which simulates reaching above shoulder and pulling downward on a crossbar (BTE Manual,1986). The BTE will be used in the automatic mode and will be set at a resistance level determined by the subjects during the familiarization session.

Metabolic Measurement Cart:

While the subjects are working on the BTE, and during peak VO_2 testing, the physiological responses will be continually monitored using an automated metabolic cart (MMC)(Sensormedics Corporation, Anaheim, California). This instrument measures the minute ventilation (V_E), a sample of which is dried and analyzed for its oxygen and carbon dioxide concentrations. Absolute VO_2 (L/min) and VCO_2 (L/min) will then be calculated from this data using the Haldane transformation with the help of a computerized software package available with the instrument. The heart

rate will be monitored with an EKG with bipolar leads in the CM_5 position. The analogue signal from the EKG will be transmitted to the MMC which calculates the heart rate along with the metabolic variables. These variables include respiratory exchange ratio (RER), calculated as a ratio between VCO_2 and VO_2; oxygen pulse (O_2 pulse, ml/beat), calculated as the ratio between the VO_2 and the heart rate; ventilatory equivalent for oxygen (V_E/VO_2), calculated as the ratio between expired ventilation V_E and VO_2; and ventilatory equivalent for carbon dioxide (V_E/VCO_2), calculated the ratio between V_E and VCO_2 (Beckman, 1983).

The MMC has been demonstrated to be a valid instrument in a variety of exercise modes (treadmill, bicycle and arm ergometer) in contrast to other metabolic measurement devices (Wilmore & Norton, 1976). Tester skill level and experience was shown to have no effect on test scores. As well, the results of validity testing show the MMC to be at least as accurate as the best instruments it was compared against (Norton, 1982).

Percent Body Fat:

Body fat was determined from electrical impedance testing using the RJL Systems BIA - 101 Body Composition Analyzer. This procedure has been shown to be a reliable and valid in determining percent body fat. Jackson et al., (1988) compared bioelectrical impedance to skinfold fat and

hydrostatic weighing methods and reported correlations between 0.96 to 0.98 in young healthy subjects.

Peak Oxygen Uptake Test:

Testing will be completed using the Monark 881 arm cranking ergometer. Physiological responses will be monitored by the MMC as described above. Heart rate will be recorded using an electrocardiogram (Hewlett Packard, Model 1500B, Washington) which will be interfaced with the MMC. A description of testing protocol will be given in the following chapter.

Wingate Power Test:

In this study, computerized measurements of anaerobic power was obtained using a modified arm ergometer described by Bhambhani, Kuwajima, Fleming, Rodgers, Gomes, & Wenger (1991). The modifications include the application of a sensing element where one side of the wheel has been painted black and eight self adhesive silver reflective tape has been applied equal distance apart. A photoelectric transducer was used to read the number of rotations. The ergometer was connected to a computer using a customized program where the following results will be calculated every .5 seconds: revolutions per minute, power output in Watts, Watts.kg-1, and Watts.kg-1 of lean body mass and work done in kilojoules (Bhambhani, et al., 1991). Test protocol of

the Wingate Power Test will follow the traditional 30 second method using a Monark Rehab. 881 arm ergometer which has been shown in the literature review to be valid and reliable. The resistance (load factor) for the arm test will be 50 g/kg for males and 45 g/kg for females (Dotan and Bar-Or 1983).

REFERENCES

Anderson, P.A., Chanoski, C.E., Devan, D.L., McMahon, B.L., & Whelan, E.P. (1990). Normative study of grip and wrist flexion strength employing a BTE Work Simulator. Journal of Hand Surgery, 15A, 420-425.

Armstrong, T. J. & Silverstein, B.A. (1987). Upper extremity pain in the workplace - role of usage in casualty. In Clinical concepts in regional musculoskeletal illness (pp. 333-354). Grune & Stratton, Inc.

Astrand, P.O., Rodahl, K. (1986). Textbook of Work Physiology - Physiological Bases of Exercise. Toronto: McGraw Hill Book Company.

Baltimore Therapeutic Equipment Company (1986). Operations manual for the Baltimore Therapeutic Equipment Work Simulator (3rd ed.). Baltimore.

Bar-or, O. (1987). The Wingate anaerobic test: An update on methodology, reliability, and validity. Sports Medicine, 4, 381-394.

Ben Ari, E., Inbar, O., & Bar-Or, O. (1975). The aerobic capacity and maximal anaerobic power of 30 to 40 year-old men and women. Biomechanics of Sport and Kinanthropometry, Book 6, Proceedings of the International Congress of Physical Activity Sciences, 38, 424-426.

Berlin, S., & Vermette, J. (1985). An exploratory study for work simulator norms for grip and wrist flexion. Vocational Evaluation and Work Adjustment Bulletin, Summer, 61-65.

Bell, G.J., Petersen, H., Quinney, H.A., & Wenger, H.A. (1989). The effect of velocity-specific strength training on peak torque and anaerobic rowing power. Journal of Sports Medicine, 7, 205-214.

Bhambhani, Y., Kuwajima, F., Fleming, A., Rodgers, E., Gomes, P. & Wenger, H. (1991). Increased sensitivity of Wingate test results using a computerized system for evaluation system. Proceedings of the Annual General Meeting of the Canadian Association of Sport Sciences, (pp. 34). Kingston, Ontario, Canada.

Borg, G.A. (1982). Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise, 14(5), 377-381.

Borg, G.A., Noble, B.J. (1974). Perceived exertion. Exercise and Sport Sciences Review. New York: Academic Press Inc.

Bouchard, C., Taylor, A.W., Simoneau, J.A., & Dulac, S. (1991). Testing maximal anaerobic power and capacity. In J.D. MacDougall, H.A. Green (eds.) Physiological Testing of the High-Performance Athletes, 2nd ed. Canadian Association of Sports Sciences.

Brown, J.R., & Crowden, G.P. (1963). Energy expenditure ranges and muscular work grades. British Journal of Industrial Medicine,20, 277-283.

Canadian Classification and Dictionary of Occupations Guide (1986). Ottawa: Canadian Government Publishing Centre.

Ceci, R., & Hassmen, P. (1991). Self-monitored exercise at three different RPE intensities in treadmill vs field running. Medicine and Science in Sports and Exercise, 23(6), 732-738.

Chaffin, D. B., & Andersen, G. (1984). Manual materials handling limits. In Occupational biomechanics. Toronto: John Wiley & Sons.

Coutts, K.D. & Stogryn, J.L. (1987). Aerobic and anaerobic power of Canadian wheelchair track athletes. Medicine and Science in Sports and Exercise, 19(1), 62-65.

Craig, N.P., Pyke, F.S., & Norton, K.I. (1989). Specificity of test duration when assessing the anaerobic lactacid capacity of high-performance track cyclists. International Journal of Sports Medicine, 10, 237-242.

Curtis, R.M., & Engalitcheff, J., Jr. (1981). A work simulator for rehabilitating the upper extremity - preliminary report. Journal of Hand Surgery, 6(5), 499-501.

Davis, P.O., & Dotson, C.O. (1986). Job performance testing: an alternative to age discrimination. Medicine and Science in Sports and Exercise, 19(2), 179-185.

Davis, P.O., Dotson, C.O., & Laine Santa Maria, D. (1982). Relationship between simulated fire fighting tasks and physical performance measures. Medicine and Science in Sports and Exercise, 14, 65-71.

Debryyn-Provost, P., Sturbois, X. (1984). Physiological response of girls to aerobic and anaerobic endurance tests. Journal of Sports Medicine,24, 149-154.

DiCarlo, S.E., Supp, M.D., & Taylor, H.C. (1983). Effect of arm ergometry training on physical work capacity of individuals with spinal cord injuries. Physical Therapy, 63(7), 1104-1107.

Dotan, R., & Bar-Or, O. (1983). Load optimization for the Wingate anaerobic test. European Journal of Applied Physiology, 51, 409-417.

Dunbar, C.C., Robertson, R.J., Baun, R., Blandin, M.F., Metz, K., Burdett, R., & Goss, F.L. (1992). The validity of regulating exercise intensity by ratings of perceived exertion. Medicine and Science in Sports and Exercise, 24(1), 94-99.

Gamberale, F. (1985). The perception of exertion. Ergonomics, 28(1), 299-308.

Greenberg, G.J., Berger, R.A. (1983). A model to assess one's ability to apprehend and restrain a resisting suspect in police work. Journal of Occupational Medicine, 25(11), 809-813.

Hakkinen, K., & Sinnemaki, P. (1990). Maximum oxygen uptake, anaerobic power and neuromuscular performance characteristics in bandy players of two different competitive levels. The Journal of Sports Medicine and Physical Fitness, 30(1), 67-73.

Holmes, D. (1985). The role of the occupational therapist - work evaluator. American Journal of Occupational Therapy, 39(5), 308-313.

Hutchinson, P.L., Cureton, K.J., & Outz, H., & Wilson, G. (1991). Relationship of cardiac size to maximal oxygen uptake and body size in men and women. International Journal of Sports Medicine, 12, 369-373.

Jackson, A.S., Pollock, M.L., Graves, J.E., & Mahar, M.T. (1988). Reliability and validity of bioelectrical impedance in determining body composition. Journal of Applied Physiology, 64(2), 529-534.

Jacobs, I. (1980). The effects of thermal dehydration on performance of the Wingate anaerobic test. International Journal of Sports Medicine, 1, 21-24.

Kennedy, L.E., & Bhambhani, Y.N. (1991). The Baltimore Therapeutic Equipment work simulator: reliability and validity at three work intensities. Archives of Physical Medicine Rehabilitation, 72, 511-516.

Kerlinger, F.N., (1973). Foundations of Behavioral Research 2nd Ed. Holt Rinehart Winston Inc New York.

King, J.W., & Berryhill, B.H. (1991). Assessing maximum effort in upper extremity functional testing. Work, 1, 65-76.

Knapik, J.J., Burse, R.L., & Vogel, J.A. (1983). Height, weight, percent body fat, and indices of adiposity for young men and women entering the U.S. army. Aviation, Space, and Environmental Medicine, March, 54(3), 223-231.

Knapik, J.J., Wright, J.E., Kowal, D.M., & Vogel, J.A. (1980). The influence of U.S. army basic initial entry training on the muscular strength of men and women. Aviation, Space, and Environmental Medicine, October,51(10), 1086-1090.

Komi, P.V., Rusko, H., Vos, J., & Vihko, V. (1977). Anaerobic performance capacity in athletes. Acta Physiologica Scandinavia,100(1), 107-114.

Leon, A.S. (1986). Age as a criterion for work performance - chronologic vs physiologic age. Medicine and Science in Sports and Exercise, 19(2), 157-158.

Lepping, V. (1990). Work hardening: a valuable resource for the occupational health nurse. American Association of Occupational Health Nurse Journal, 38(7), 313-317.

Lloyd, C., & Fiqir, N. (1990). Vocational evaluation: the use of work samples. Australian Occupational Therapy Journal.

Loeppky, J.A., & Luft, U.C. (1989). Work capacity, exercise responses and body composition of professional pilots in relation to age. Aviation, Space, and Environmental Medicine, November,60(11), 1077-1084.

Manning, J.M., Dooly-Manning, C., & Perrin, D.H. (1988). Factor analysis of various anaerobic power tests. Journal of Sports Medicine and Physical Fitness, 28(2), 138-144.

Matheson, L., Ogden, L.D., Violette, K., & Shultz, K. (1985). Work hardening: occupational therapy in industrial rehabilitation. American Journal of Occupational Therapy, 39, 314-321.

Maud, P.J., & Schultz, B.B. (1986). Gender comparisons in anaerobic power and anaerobic capacity tests. British Journal of Sports Medicine, 20, 51-54.

Mayers, N., Gutin, B. (1979). Physiologic characteristics of elite prepubertal cross-country runners. Medicine and Science in Sports, 11(2), 172-176.

McArdle, W.D., Katch, F.J., & Katch, V.L. (1991). Exercise Physiology, Energy, Nutrition, and Human Performance, (3rd ed.) Philadelphia: Lea & Febiger.

McLure, P.W., & Flowers, K.R. (1992). The reliability of BTE work simulator measurements for selected shoulder and wrist tasks. Journal of Hand Therapy, 5, 25-28.

Montgomery, D.L. (1988). Physiology of ice hockey. Sports Medicine, 5, 99-126.

Nebelsick-Gullett, L.J., Housh, T.J., Johnson, G.O., & Bauge, S.M. (1988). A comparison between methods of measuring anaerobic work capacity. Ergonomics, 31(10), 1413-1419.

Noble, B.J. (1982). Clinical applications of perceived exertion. Medicine and Science in Sports and Exercise, 14(5), 406-411.

Noble, B.J., Borg, G.A.V., Jacobs, I., Ceci, R., & Kaiser, P. (1983). A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. Medicine and Science in Sports and Exercise, 15(6), 523-528.

Ogden-Niemeyer, L., & Jacobs, K. (1989). Work Hardening: State of the Art. Thorofare, NJ: Slack Inc.

Oyster, C.K., Hanten, W.P., & Llorens, L.A. (1987). Introduction to Research: A Guide for the Health Science Professional. Philadelphia: J.B. Lippincott Co.

Pandolf, K.B. (1982). Differentiated ratings of perceived exertion during physical exercise. Medicine and Science in Sports and Exercise, 14(5), 397-405.

Pandolf, K.B. (1983). Advances in the study and applications of perceived exertion. Exercise and Sport Sciences Reviews, 11, 118-158.

Patton, J.F., Daniels, W.L., & Vogel, J.A. (1980). Aerobic power and body fat of men and women during army basic training. Aviation, Space, and Environmental Medicine, May, 492-496.

Patton, J.F., Murphy, M.M., & Frederick, F.A. (1985). Maximal power outputs during the Wingate anaerobic test. International Journal of Sports Medicine, 6, 82-85.

Patton, J.F., Morgan, W.P., & Vogel, J.A. (1977). Perceived exertion of absolute work during a military physical training program. European Journal of Applied Physiology, 36, 107-114.

Pendergraft, K.J., Cooper, J.K., & Clark, G.L. (1990). The BTE work simulator. Rehabilitation of the Hand 3rd Ed., (pp. 1210-1213). St Louis.: C.V. Mosby Company

Powell, D.M., Zimmer, C.A., Antoine, M.M., Baruch, L.D., Bellian, K.T., Morgan, R.F., & Edlich, R.F. (1991). Computer analysis of the performance of the BTE work simulator. Journal of Burn Care and Rehabilitation, 12, 150-256.

Prampero, P.E., Limas, F.P., & Sassi, G. (1970). Maximal muscular power, aerobic and anaerobic, in 116 athletes performing at the XIXth Olympic games in Mexico. Ergonomics, 13(6), 665-674.

Purvis, J.W., & Cureton, K.J. (1981). Ratings of perceived exertion at the anaerobic threshold. Ergonomics, 24, 295-300.

Rodgers, S.H. (1988). Job evaluation in worker fitness determination. Occupational Medicine, 3(2), 219-239.

Sawka, M.N. (1986). Physiology of upper body exercise. In K.B. Pandolf (Ed.). Exercise and Sport Sciences Reviews, Vol. 14 (pp. 175-211). New York: MacMillan Press.

Sharkey, B.J. (1987). Functional vs chronological age. Medicine and Science in Sports and Exercise, 19(2), 174-177.

Sharp, M.A., Harman, E., Vogel, J.A., Knapik, J.J., & Legg, S.J. (1988). Maximal aerobic capacity for repetitive lifting: comparison with three standard exercise testing modes. European Journal of Applied Physiology, 57, 753-760.

Shephard, R.J. (1987). Human rights and the older worker: changes in work capacity with age. Medicine and Science in Sports and Exercise, 19(2), 168-173.

Shephard, R.J. (1990). Assessment of occupational fitness in the context of human rights legislation. Canadian Journal of Sports Sciences, 15(2), 89-95.

Skinner, J.S., Hustler, R., Bergsteinova, V., & Buskirk, E.R. (1973). The validity and reliability of a rating scale of perceived exertion. Medicine and Science in Sports and Exercise, 5(2), 94-96.

Skinner, J.S., Hustler, R., Bergsteinova, V., & Buskirk, E.R. (1973). Perception of effort during different types of exercise and under different environmental conditions. Medicine and Science in Sports and Exercise, 5(2), 110-115.

Smutock, M.A., Skrinar, G.S., & Pandolf, K.B. (1980). Exercise intensity: subjectivity regulation by perceived exertion. Archives of Physical Medicine and Rehabilitation, 61, 569-574.

Stamford, B.A. (1976). Validity and reliability of subjective ratings of perceived exertion during work. Ergonomics, 19(1), 53-60.

Tharp, G.D., Newhouse, R.K., Uffelman, L., Thorland, W.G., & Hohnson, G.O. (1985). Comparison of sprint and run times with performance on the Wingate anaerobic test. Research Quarterly for Exercise and Sport, 56(1), 73-76.

Thomas, S.G., Cox, M.H., LeGal. Y.M., Verde, T.J., & Smith, H.K. (1989). Physiological profiles of the Canadian national judo team. Canadian Journal of Sports Sciences, 14(3), 142-147.

Thorland, W.G., Johnson, G.O., Cisar, C.J., Housh, T.J., & Tharp, G.D. (1987). Strength and anaerobic responses of elite young female sprint and distance runners. Medicine and Science in Sports and Exercise, 19(1), 56-61.

Trossman, P.B., Suleski, K.B., & Li, P.W. (1990). Test-retest reliability and day to day variability of an isometric grip strength test using the work simulator. Occupational Therapy Journal of Research, 10, 266-279.

U.S. Department of Labour, Employment and Training Administration (1981). Selected Characteristics of Occupations Defined in the Dictionary of Occupational Titles. Washington, D.C.: U.S. Government Printing Office.

Vandewalle, H., Peres, G., Stouvenel, O., & Monod, H. (1989). Force-velocity relationship and maximal anaerobic power during cranking exercise in young swimmers. International Journal of Sports Medicine, 10, 439-445.

Van Ingen Schenau, G.J., & de Groot, G. (1983). Differences in oxygen consumption and external power between male and female speed skaters during supramaximal cycling. European Journal of Applied Physiology, 51, 337-345.

Van Ingen Schenau, G.J., De Koning, J.J., & De Groot, G. (1990). A simulation of speed skating performances based on a power equation. Medicine and Science in Sports and Exercise, 22(5), 718-729.

Van Ingen Schenau, G.J., de Boer, R.W., Geysel, J.S.M., & de Groot, G. (1988). Supramaximal test results of male and female speed skaters with particular reference to methodological problems. European Journal of Applied Physiology, 57, 6-9.

Watson, R.C., & Sargeant, T.L.C. (1986). Laboratory and on-ice test comparisons of anaerobic power of ice hockey players. Canadian Journal of Applied Sport Sciences, 218-224.

White, A.T., & Johnson, S.C. (1991). Physiological comparison of international, national, and regional alpine skiers. International Journal of Sports Medicine, 12, 374-378.

Wilke, N.A., Sheldahl, L.M., Dougherty, S.M., Levandoski, S.G., & Tristani, F.E. (1993). Baltimore Therapeutic Equipment Work Simulator: Energy expenditure of work activities in cardiac patients. Archives of Physical Medicine and Rehabilitation, 74, 419-424.

Wilmore, J.H., Davis, J.A. & Norton, A.C.(1976). An automated system for assessing metabolic and respiratory function during exercise. Journal of Applied Physiology, Vol. 40, 619-624.

Yeater, D. (1987). The occupational health nurse as disability manager: a vital health care management strategy. American Association of Occupational Health Nurse Journal, 35(33), 116-118.

CHAPTER II

GENDER COMPARISONS FOR SIMULATED HIGH INTENSITY UPPER BODY WORK CAPACITY

INTRODUCTION

Research in the area of physical work capacity testing is continuously expanding. A major reason for this increase has been the need to reduce costs of hiring inappropriate applicants for a specific type of work (Greenberg & Berger, 1983). Similar assessment may also be used as an alternative to mandatory retirement and gender discrimination (Davis & Dotson, 1987; Leon 1987; Sharkey, 1987; Shephard, 1990; Shephard, 1987). In certain occupations, specific tasks require high intensity effort such as restraining a resisting suspect in police work (Greenberg & Berger, 1983), or the many tasks associated with fire fighting (Davis, Dotson, & Santa Maria, 1982). These two occupations are examples of areas where it is especially imperative to have a valid assessment tool to assess the job applicant's ability to do high intensity work at the standards required so as to ensure the individual's safety.

Fitness assessments are regularly carried out as part of the above mentioned physical capacity evaluations for job screening or as part of rehabilitation programs. Generally, actual field performance test results are accepted more

readily than the usual laboratory fitness tests (Shephard, 1990; Rodgers, 1988). Occupational therapists are well suited to design and implement such physical capacity evaluations (which are more closely related to actual work tasks) due to their training in task analysis and a philosophical base which requires the use of activity in work related evaluations (Lloyd & Fiqir, 1990; Matheson, Ogden, Violette, & Shultz, 1985). Through the use of activity, the occupational therapist can fulfil the role of a work evaluator which includes work orientated treatment, job analysis, work tolerance screening, work capacity evaluation, and work hardening (Holmes, 1985).

A method often used by occupational therapists as part of physical capacity testing for both vocational screening and rehabilitation purposes is work simulation (Matheson, Ogden, Violette, & Shultz, 1985; Ogden-Niemeyer & Jacobs, 1988). Through work simulation, the therapist can reproduce actual job tasks as closely as possible. This will often involve the use of tools, equipment, material, work environment, etc. Advances in technology and the need for measurable objective data and increased versatility in terms of uses has led to the development of electronic work simulators (Ogden-Niemeyer & Jacobs, 1988). One of these is the Baltimore Therapeutic Equipment work simulator (BTE). The BTE was developed by Engalitcheff Jr. and Curtis in 1979 and its primary purpose was for rehabilitation and

evaluation of upper extremity performance (Pendergraft, Cooper, & Clark, 1990). It was designed to simulate a wide variety of normal movements with its 21 attachments (Curtis & Engalitcheff, 1981; Powell, Zimmer, Antoine, Baruch, Bellian, Morgan, & Edlich, 1991). The primary advantage of using the BTE as compared to actual work tasks is that it allows for measurement of objective data. These include resistance, distance, time and specifically torque, work done and power output (Curtis & Engalitcheff, 1981; Pendergraft et al, 1990; Powell et al, 1991; & BTE manual, 1986). Such objective measurements would otherwise be difficult to obtain except through indirect methods such as monitoring heart rate and oxygen consumption (Kennedy & Bhambhani, 1991).

The occupational therapist must be aware of any gender differences or lack of, to prevent gender discrimination and inappropriate job placement. In the past, job screening was done by separating those individuals who could perform the job from those who could not. This led to informal groupings of traditional men's and women's jobs with little crossover, until legislation enacted in the early 1970's made it illegal to use gender as a selection tool for employment (Rodgers, 1988, pg. 223). Shephard (1990) reports that although legislation requires equal treatment, it does not prevent employers from practising differential treatment if they can demonstrate differences in gender that would

prevent a worker from performing certain duties.

Through traditional fitness measures, gender differences have already been established. There appears to be no significant difference between gender before puberty but, thereafter, males tend to have greater muscle mass, strength, respiratory function, maximal oxygen uptake, body size and cardiac output, and lesser percent body fat than females (Astrand & Rodahl, 1986; McArdle, Katch & Katch, 1991). Whether these differences in fitness translate into differences in work capacity needs to be investigated.

If the BTE is to be used for job screening and rehabilitation, gender differences in terms of performance at the biomechanical and physiological level must be established. Although there have been several studies which have evaluated specific aspects of performance on the BTE, only one has specifically looked at gender differences. Berlin and Vermette (1985) used the BTE to compare grip and wrist flexion between males and females. Overall, the mean scores for males were approximately 42-57% greater than for females. This study was limited in that it only looked at maximal biomechanical performance and not at repetitive work performance, and it did not measure any physiological responses.

The purpose of this study was to compare males and females for the biomechanical and physiological responses during three upper extremity high intensity tasks performed

on the BTE work simulator at a rating of perceived exertion (RPE) of 15 (hard) on the Borg Scale.

METHODS

Subjects:

The subjects consisted of twenty healthy males and 20 healthy females who were primarily graduate and undergraduate students at the University of Alberta. The subjects volunteered their informed consent (Appendix A1) to participate in this study, which had been approved by an ethics committee of the faculty. As the goal of the study was to apply the data to the vocational field, subjects ages were limited to 18 years and over as this is usually the start of full time employment.

Study Protocol:

Each subject was required to complete five testing sessions. These included a task familiarization session, a peak VO_2 test, and three different work simulation tasks on separate sessions.

Session 1:

A) Task familiarization:

Subjects were asked to fill out a Physical Activity Readiness Questionnaire (PAR Q) form (B.C. Ministry of Health 1978, Appendix A2) and a consent form. They were

then asked to randomly select the order of performing the three work simulation tasks on the BTE. Randomization was done by picking lots. The work tasks chosen for the study included: **tool #131**, which simulates opening a valve and turning a steering wheel (WT), **tool #171**, which simulates push-pulling an object such as a mop or heavy tools (PP) and **tool #181**, which simulates reaching above the shoulder and pulling downward on a crossbar (OR) (BTE Manual 1986). These three tasks were selected as they are included in the U.S. Department of Labour's Dictionary of Occupational Titles (DOT) list of 20 physical demands of work (1981). They are also used to categorize jobs tasks by the Canadian Classification and Dictionary of Occupations (CCDO)(1986).

The positions for the three tasks were standardized as follows. For the **WT**, the height of the shaft was adjusted so that the lower end of the wheel was at the height of the subjects umbilicus. The angle of the wheel was set at one setting towards the person from the vertical position (i.e. approximately 45 degrees). Subjects were advised to keep their trunk as stationary as possible and to place their feet side by side a comfortable distance apart. They were then asked to rotate the wheel towards their dominant arm at a constant self selected rate using only their arms.

The height for the **PP**, was adjusted so that the shaft at the level of the elbow crease. The angle of the shaft was set parallel to the ground. The subject's dominant hand

was positioned at the back end of the device with the non-dominant hand at a self-chosen comfortable position. Subjects were asked to place the foot that was contralateral to their dominant hand in the forward position, while the other foot was placed a comfortable distance behind. Subjects were advised not to "sway" their entire body while pushing or pulling and to avoid trunk rotation. They were then asked to push-pull the attachment at a constant self selected rate.

For the **OR** the height of the shaft was adjusted to the level of the axillary crease. The angle of the shaft was set parallel to the ground. Subjects were asked to place their feet a comfortable distance apart. They were also told to avoid trunk use and to ensure both arms go through their full range of motion. They were then asked to pull down on the attachment at a constant self selected pace. (NOTE: all tasks were demonstrated to the subjects during the familiarization session).

Once the order was determined, the BTE was set to the position as specified by a standardized protocol. Subjects were asked to work at a self selected rate for four minutes during which time the resistance was gradually increased. The subjects were then asked to select a work intensity corresponding to a RPE of 15 (hard) on the Borg Scale (1982) while performing the task. Even after the individual had attained a level of 15, the resistance was increased and

decreased several times to ensure a consistent rating was attained. (Note: subjects were not able to see resistance levels on the BTE.) Once the resistance was identified, the subject continued to work at that level to complete the four minutes. Subjects were given a four minute rest period between each task.

The use of the Borg scale is expanding in clinical settings and may have important applications in the occupational setting (Noble, 1982). The RPE scale is an interval scale which ranges from 6 to 20. The odd numbers correspond to descriptors ranging from 7 = very very light, to 19 = very very hard. The RPE maybe used relative to metabolic demands at higher workloads and could be used to regulate intensity of effort during vigorous effort (Dunbar, Robertson, Baun, Blandin, Metz, Burdett, & Goss, 1992; Eston, Davies, & Williams, 1987). Ceci & Hassmen, (1991), Pandolf (1982) Skinner et al., (1973) & Smutock, (1980) also found that during higher intensity self regulated exercise (RPE of 11 or higher), physiological measures were highly reliable. In terms of gender differences, the rating of perceived exertion (RPE) responses shows no significant difference when compared to percent VO_2. Absolute differences of RPE response between gender were found to be related to differences in aerobic capacity (Nobel,1982).

B) Measurement of Body Fat:

Body fat was estimated from total body water measurements using electrical impedance technique (RJL Systems BIA - 101 Body Composition Analyzer). This procedure has been shown to be a reliable and valid in determining percent body fat. Jackson, Pollock, Graves, & Mahar, (1988) compared bioelectrical impedance to skinfold fat and hydrostatic weighing methods and they were all found to be reliable where correlations ranged from 0.96 to 0.98. Subjects were tested following manufactures guidelines.

Session 2 Determination of Peak Oxygen Uptake:

During this session, the subject's peak upper extremity cardiovascular fitness level was assessed. The Monark 881 mechanically braked arm ergometer was utilized. The test protocol as described by Bhambhani, et al. (1991), was initiated at zero resistance at a cadence of 50 rpm, and the resistance was increased every two minutes by 0.5 kgs until volitional fatigue. During the entire test, physiological measurements were monitored using an automated metabolic cart (Sensormedic, Model MMC Horizon, California) which was calibrated following the manufacturer's specification using standardized gases. Heart rate (HR) was recorded using an electrocardiogram (Hewlett Packard, Model 1500B, Washington) which was interfaced with the MMC.

Sessions 3 - 5 Performance on the Work Simulator:

The following three sessions were randomly determined by the subjects who were asked to pick lots. The BTE was used in the automatic mode and was set at the resistance level corresponding to an RPE of 15 determined by the subjects during the familiarization session.
All physiological measurements, while performing the BTE work tasks, were monitored using the MMC and electrocardiogram. The subjects were asked to stand in place for three minutes to get a baseline measurement of oxygen consumption and HR. After the three minutes, the subjects worked on the BTE as described for four minutes to achieve a physiological steady state.

Calculation of Energy Expenditure

The gross energy expenditure of the work tasks (in Kcal/min and Kcal/kg/min), was calculated as a product of VO_2 (L/min) and the kilocaloric equivalent using the nonprotein RER transformation developed by Weir (1949). The mean of the steady state VO_2 during the final two minutes of the work task was used in the calculation. Net energy expenditure was calculated by subtracting the baseline standing measurement per minute from the gross energy expenditure during the work simulation task.

Statistical Analysis

The study data was analyzed using a two-factor repeated measures analysis of variance (2×3), where factor A had two levels (male and female), and factor B had three levels (the three different work simulation tasks). Summary tables of ANOVA's are presented in appendix C. Scheffe multiple comparisons were performed on an 'a priori' basis to compare the responses between males and females for each of the tasks. Results were considered to be significant at the .05 level. However, as multiple comparison were made for each area of interest the Bonferroni adjustment method (Appendix D) where the alpha level was divided by the number of comparisons was used to control for type I error (Ottenbacher, 1991). All statistical analyses were performed using SPSSx computer programs.

RESULTS

Subject Characteristics:

The subject characteristics are reported in table 1. There was no significant difference between males and females for age. However, all other anthropometric variables, namely height, weight, BMI and LBM were found to be significantly higher in males compared to females. Percent body fat was found to be significantly lower in males then females.

Peak Physiological Responses:

The peak physiological responses are presented in table 2. A significant difference was found when comparing absolute and relative peak VO_2 values between males and females. Males were found to have approximately 11.4% greater relative aerobic power than females. Males also demonstrated a significantly higher maximum heart rate and expired ventilation (V_E). No significant gender differences were noted for 0_2 pulse, RER, and V_E/VO_2 ratio.

Work Performance During Three Work Simulation Tasks:

Comparison Among Tasks:

Table 3 demonstrates a significant difference between each task within gender for torque (in-lbs) produced in both males and females. The torque produced during the OR was approximately 40% greater than the PP and 68% greater than the WT. For work (in-lb-degrees), power (W) and relative power (W/kg), the OR was significantly higher than the WT and PP tasks, which in turn, were not significantly different from each other. The OR performance ranged from 28% to 44% greater than the other two tasks for these variables.

Gender Comparison for the Three Tasks:

When comparing gender differences between tasks for biomechanical performance, males demonstrated a

significantly higher torque, work, and power for the OR (table 3). As well, males attained a significantly higher power output than females for the PP task. However, when weight was taken into account, no significant gender difference was found for power output (watts/kg) for any of the tasks.

Physiological Responses During Three Work Simulation Tasks: Comparison Among Tasks:

Tables 4 and 5 represent the means and standard deviations (SD) for the physiological responses and energy expenditure values respectively, during the work simulation tasks in males and females. When comparing tasks within gender, no significant difference was found for any of the steady state physiological responses.

When comparing energy expenditure for each task within gender, no statistical difference was found for any of the variables except the net energy cost in cal/watt/kg. OR values were significantly lower than those of the other two tasks for both males and females.

Gender Comparison for the Three Tasks:

When comparing differences between gender for the same task, no significant difference was found for all physiologic variables except for absolute VO_2 and oxygen uptake per heartbeat (O_2 pulse). The absolute VO_2 was

significantly higher in males by 30% during the WT and PP tasks. Values for the OR were 25% higher in males and was approaching significance. Male O_2 pulse was also observed to be approximately 30% greater than the female for all three tasks. Subjects were found to be working at approximately 50% of their peak VO_2 and 70% of peak HR observed during the arm crank test for all three tasks.

Baseline figures for energy consumption while standing were found to be significantly higher in males compared to females for all three tasks. Males gross energy cost for the WT and PP task were significantly higher than females. Males were also found to have a statistically greater net energy cost of work (kcal/min) for PP. When comparing net energy cost of work per unit amount of power relative to the subjects body weight (NEC in cal/watt/kg), males were found to consume a significantly lower amount of energy as compared to females for both the PP and OR. It is worth noting that WT values were similar to the PP and OR values and were approaching significance.

DISCUSSION

This study has initiated the comparison between genders at both the biomechanical and physiologic level for high intensity upper body work on the BTE work simulator. Significant task specific differences were observed both within and between gender. With further study in this area

the results of the study may allow for better methods of job screening and pre-employment preparation.

1) Peak Physiological Responses

Females were observed to have approximately 11% lower peak VO_2 as compared to males. This may be attributed in part to lower peak HR responses. Both males and females did not reach their age predicted maximum HR. Sawka (1986) reported that for arm work, maximum HRs are usually approximately 93% of age predicted maximum. Males peak HR responses were approximately 94% while female were at 89% of age predicted maximum. This lower HR for females may in part be related to the lower VO_2 responses. In addition, the greater amount of fat and lower haemoglobin levels for females compared to that of males may account for the remaining difference in VO_2 (McArdle et al, 1991).

The V_E values were significantly different for males and females, however the values were in line with data reported by Astrand and Rodahl 1986, in which males consumed approximately 30 L/min of oxygen more than females for similar type of exercise. Although V_E was significantly different, no difference was noted for ventilatory equivalent for oxygen (V_E/VO_2). As well, no significant difference was noted for RER and O_2 pulse. Overall the peak physiological responses indicate that subjects were within normal limits (Astrand & Rodahl, 1986; McArdle et al, 1991;

Sawka, 1986) and may be considered to be representative of this age and gender group that may be seeking employment.

2) Task Specific Differences Within Gender:

The results of this study may be used by occupational therapists for normative purposes for these specific tasks on the BTE only. Although many of the physiological responses were similar for most tasks within gender, there were some observed biomechanical differences. The amount of torque produced was significantly different between all tasks within gender. An explanation for these similar differences within gender may be that each task was performed on different planes. In addition, the lever arm for each task was different. The length from the axis of rotation was greatest for the OR and shortest for the WT. This also corresponds to the greatest amount of torque output for OR and least for WT.

The biomechanical results for work (in/lb/degrees), power (watts) and relative power (watts/kg) demonstrated a significant difference between the OR and the PP and WT. However, no difference was found between WT and PP. Both of these tasks are performed below shoulder level and the lever arm length difference was not as large as compared to the OR.

Most of the physiological responses evoked by the three tasks were similar. The similar responses may be due to

subjects being required to work at a perceived exertion of 15. The Borg scale has been shown to be a valid measure of physiological work intensity (Dunbar et al, 1992 & Eston et al, 1987). This may further attest to the reliability of this scale to accurately gauge work intensity. The only response observed to be significantly different was NEC cal/watt/kg. The OR responses for work, power, and relative power were higher than the other tasks, however, net energy cost expressed relative to the body weight and power generated was lower. This suggests that both males and females were working more efficiently during the OR task as compared to the WT and PP tasks.

The therapist who plans to use the BTE work simulator as an assessment or rehabilitation tool would have to consider all of these task specific biomechanical and physiological differences and not base any conclusions solely on absolute torque, work and power values. The therapist must also be aware of all the task specific differences and not assume similar responses for different tasks performed at the same perceived intensity. Furthermore, due to the specific difference between each task, whether biomechanical or physiological, it is important for the therapist to include testing of the muscle used during the actual work task (Rodgers, 1988; Sawka, 1986). As well, the therapist should consider including as many tasks as possible, to ensure the evaluation is as

comprehensive as possible (Lechner, Roth & Straaton 1991). Through an assessment battery that includes a variety of tasks, the occupational therapist may be able to gain a more accurate view of a client's functioning and a better account of task specific differences.

3) Gender Differences Between Tasks:

Changing legislation and the erosion of traditional gender barriers in the work force has brought about a need for new assessment and rehabilitation procedures (Rodgers, 1988; Shephard, 1990). It has already been demonstrated that there are significant differences in performance between males and females through traditional fitness testing (Astrand & Rodahl, 1986; McArdle et al 1991; Sawka 1986). With this in mind it is imperative that the occupational therapist be aware as to whether these differences are present in work performance. When examining biomechanical responses, although not statistically significant, a general trend of lower output values for females was observed. In addition, several task specific gender differences were also observed. While working at a perceived exertion of "hard", male output for the OR task was observed to be significantly greater for torque, work, and power (watts). The only other significant difference observed was for the PP task. Again, males produced significantly greater values then females in terms of

absolute power output. These difference may be attributed primarily to differences in size between males and females. When weight was factored into the results, no difference was found between any of the tasks for power output (watts/kg). These finding are similar to those of Jamnik & Gledhill (1992) who found that increased performance was largely related to body size.

The statistically significant differences and the general trend of lower biomechanical output response for females has significant implication in the work setting. For example, if a push pull task similar to the PP task on the BTE requires 130 in/lbs of torque, the average male subject from the study would be performing the task at an RPE of 15 (hard). An average female from the study produced a torque output of approximately 97 in/lbs for the PP task at an RPE of 15. Theoretically, a woman would have to increase her output to match the job demands which would probably cause an increase in RPE. This has implication in terms of amount of work stress an individual has to or should endure during a work day.

Physiological stress on an individual during a work task is usually determined by measuring VO_2 and HR (Gangelhoff, Cordain, Tucker, & Sockler, 1988; McArdle et al, 1991). For this study the subjects were asked to work at an RPE of 15. In both sexes they were observed to be working at approximately 50% of peak VO_2 (L/min,L/min/kg)

and 70% of peak HR.

Generally most physiological responses were similar for males and females. The only observed differences were in absolute VO_2, O_2 pulse and NEC (cal/watt/kg). Absolute VO_2 was noted to be significantly higher in males for the WT and PP, while the OR was approaching significance. These differences were not observed when VO_2 was examined relative to body weight. It is also interesting to note that no significant difference was observed for O_2 pulse during peak aerobic testing but a significant difference was found during each of the work simulation tasks. Female O_2 pulse was observed to be approximately 30% less than males. This difference can be expected as O_2 pulse has been shown to be proportional to heart size, which is also proportional to body size (Astrand & Rodahl, 1986). The difference was usually found to be approximately 25% (McArdle et al, 1991). The most significant physiological difference observed between males and females was the NEC (cal/watt/kg). Males were found to expend less energy to produce the same amount of work for both the WT and the PP tasks. The difference in response for the OR was also found to be approaching significance. This is interesting as baseline values indicate males expend more energy at rest as compared to females.

The study results indicate that the majority of physiological responses except for absolute VO_2 and O_2 pulse

were similar for both genders, this supports conclusions drawn by Nobel (1982). He found no significant difference for physiological responses between males and females performing various lifting tasks at the same RPE except for absolute VO_2. However, when the VO_2 values were compared relative to percent of peak VO_2 as was done in this current study, no significant difference was observed (1982). Occupational therapists may, therefore be able to use the Borg scale as part of their assessment or treatment procedures to determine perceived work intensity as they can assume that at similar RPE the physiological responses of males and females will also be similar.

The study results have clinical significance when biomechanical performance is considered along with the physiological responses. For females to complete a similar task, they may have to increase their physiological output to accommodate for the higher biomechanical requirement of the task. These conclusions are similar to those made by Gangelhoff et al, (1988). They compared the physiological responses for males and females on submaximal arm level and arm crank tasks. Their protocol called for males and females to work at the same workload and not base resistance on RPE as was done in this study. They observed that in general women had significantly higher physiological values to produce work at the same intensity as the males for both tasks (1988). In addition, females were found to be less

efficient in terms of energy expenditure during the upper body work simulation task, this may further increase the physiological stress incurred. Hughes & Goldman (1970) found that subjects working at varying levels of "hard" work automatically adjusted their work intensity to achieve a similar energy expenditure rate. A person who has to tax their work capacity beyond what they can comfortably do at a "hard" level may further increase the overall work stress both mentally and physically (Hughes & Goldman, 1970; Rodgers, 1988).

4) Implications for Occupational Therapists:

These results have several implications for an occupational therapist who may be developing a screening protocol for a specific job or a rehabilitation program. Precaution should be taken to prevent undue stress on the worker as well as prevent possibility of injury due to fatigue. This study suggests that for certain tasks on the BTE, females would be under increased physiological stress to produce similar biomechanical output as compared to a male. The increased discomfort and distraction caused by the increased physiological stress may influence motivation and effect the individuals' ability to fully relax their muscles (Rodgers 1988).

Although this study has demonstrated task specific and gender differences, this should not lead to job screening

based solely on worker categories. Instead, testing should be done on an individual basis to ensure no discrimination occurs. To prevent undue work stress for workers entering a specific job, the occupational therapist must look at increasing the capacity of the person through job specific work hardening or on the job training (Ogden-Niemeyer & Jacobs 1989; Rodgers, 1989). Another area that needs to be addressed is task modification in terms of equipment and actions to minimize individual differences.

5) Limitations of the Study:

For the occupational therapist intending to use the results of this study for either comparison with regards to norms or gender differences, specific limitations must be kept in mind. The first limitation is the sample. Due to recruitment methods, the background of all subjects was homogeneous, (ie. either students at the university or associated with the university in some way) and with ages that ranged from 18 to 39 years. Work capacity has been shown to decrease with age (Astrand & Rodahl, 1986). Therefore, this sample population may be significantly different in terms of age and physical capacity from the average injured blue collar worker for whom the physical capacity testing is usually intended.

Another limitation is that the study only examines three of the 20 physical work demands listed by the U.S.

department of labour. The response for the three tasks chosen for the study may be significantly different from the remaining 17. Further research is necessary to elucidate the gender differences, if any, for the remaining tasks in the identified list.

The final limitation is the validity of the BTE to duplicate actual work tasks. Wilke, Sheldahl, Dougherty, Levardoski and Tristani (1993) found a tendency for the metabolic respons on the BTE to be lower than that of actual activities. A factor that may have lowered the energy expenditure requirements for some of the activities on the BTE compared to the actual work tasks, was thought to be the inability of the BTE to duplicate the multiple integrated components and total body movements of actual work tasks.

REFERENCES

Astrand, P.O., Rodahl, K. (1986). Textbook of Work Physiology - Physiological Bases of Exercise. Toronto: McGraw Hill Book Company.

Baltimore Therapeutic Equipment Company (1986). Operations manual for the Baltimore Therapeutic Equipment Work Simulator (3rd ed.). Baltimore.

Berlin, S., & Vermette, J. (1985). An exploratory study for work simulator norms for grip and wrist flexion. Vocational Evaluation and Work Adjustment Bulletin, Summer, 61-65.

Bhambhani, Y. Gomes, P., & Erikson, P. (1991). Transfer effects of endurance training with the arms and legs. Medicine and Science in Sports and Exercise, 23, 1035-1041.

British Columbia Ministry of Health and the Department of National Health and Welfare (1978). PAR Q Validation Report.

Canadian Classification and Dictionary of Occupations Guide (1986). Ottawa: Canadian Government Publishing Centre.

Ceci, R., & Hassmen, P. (1991). Self-monitored exercise at three different RPE intensities in treadmill vs field running. Medicine and Science in Sports and Exercise, 23(6), 732-738.

Curtis, R.M., & Engalitcheff, J., Jr. (1981). A work simulator for rehabilitating the upper extremity - preliminary report. Journal of Hand Surgery, 6(5), 499-501.

Davis, P.O., & Dotson, C.O. (1987). Job performance testing: an alternative to age discrimination. Medicine and Science in Sports and Exercise, 19(2), 179-185.

Davis, P.O., Dotson, C.O., & Laine Santa Maria, D. (1982). Relationship between simulated fire fighting tasks and physical performance measures. Medicine and Science in Sports and Medicine, 14(1), 65-71.

Dunbar, C.C., Robertson, R.J., Baun, R., Blandin, M.F., Metz, K., Burdett, R., & Goss, F.L. (1992). The validity of regulating exercise intensity by ratings of perceived exertion. Medicine and Science in Sports and Exercise, 24(1), 94-99.

Eston, R.G., Davies, B.L., & Williams, J.G. (1987). Use of perceived effort ratings to control exercise intensity in young healthy adults. European Journal of Applied Physiology, 56, 222-224.

Fox, E.L., Bowers, R.W., & Foss, M.L. (1988). The Physiological Basis of Physical Education and Athletics (4th ed.). Dubuque Iowa: William C. Brown Publishers.

Gangelhoff, J., Cordain, L., Tucker, A., & Sockler, J. (1988). Metabolic and heart rate responses to submaximal arm lever and arm crank ergometry. Archives of Physical Medicine and Rehabilitation, 69, 101-105.

Greenberg, G.J., Berger, R.A. (1983). A model to assess one's ability to apprehend and restrain a resisting suspect in police work. Journal of Occupational Medicine, 25(11), 809-813.

Holmes, D. (1985). The role of the occupational therapist - work evaluator. American Journal of Occupational Therapy, 39(5), 308-313.

Hughes, A.L., & Goldman, R.F. (1970). Energy cost of "hard work". Journal of Applied Physiology, 29(5), 570-572.

Jackson, A.S., Pollock, M.L., Graves, J.E., & Mahar, M.T.(1988). Reliability and validity of bioelectrical impedance in determining body composition. Journal of Applied Physiology, 64(2), 529-534.

Jamnik, V.K., & Gledhill, N. (1992). Development of fitness screening protocols for physically demanding occupations. Canadian Journal of Sport Sciences, 17(3), 222-227.

Kennedy, L.E., & Bhambhani, Y.N. (1991). The Baltimore Therapeutic Equipment work simulator: reliability and validity at three work intensities. Archives of Physical Medicine and Rehabilitation, 72, 511-516.

Lechner, D., Roth, D., & Straaton, K. (1991). Functional capacity evaluation in work disability. Work, 1(3), 37-47.

Leon, A.S. (1986). Age as a criterion for work performance - chronologic vs physiologic age. Medicine and Science in Sports and Exercise, 19(2), 157-158.

Lloyd, C., & Fiqir, N. (1990). Vocational evaluation: the use of work samples. Australian Occupational Therapy Journal.

Matheson, L.N. (1986). Work Capacity Evaluation. Employment and Rehabilitation Institute, Anaeheim, California.

Matheson, L., Ogden, L.D., Violette, K., & Shultz, K. (1985). Work hardening: occupational therapy in industrial rehabilitation. American Journal of Occupational Therapy, 39, 314-321.

McArdle, W.D., Katch, F.J., & Katch, V.L. (1991). Exercise Physiology, Energy, Nutrition, and Human Performance, (3rd ed.) Philadelphia: Lea & Febiger.

Niemeyer, L., Matheson, L.N., & Carlton, R.S. (1989). Testing consistency of effort: BTE Work Simulator. Industrial Rehabilitation Quarterly, 2, 5-32.

Noble, B.J. (1982). Clinical applications of perceived exertion. Medicine and Science in Sports and Exercise, 14(5), 406-411.

Ogden-Niemeyer, L., & Jacobs, K. (1988). Work Hardening: State of the Art. Slack Incorporated: Thorofare, NJ.

Ottenbacher, K.J. (1991). Statistical conclusion validity - multiple Inferences in rehabilitation medicine American Journal of Physical Medicine and Rehabilitation, 70(6), 317-322.

Pandolf, K.B. (1982). Differentiated ratings of perceived exertion during physical exercise. Medicine and Science in Sports and Exercise, 14(5), 397-405.

Pendergraft, K.J., Cooper, J.K., & Clark, G.L. (1990). The BTE work simulator. In Hunter, J.M., Schneider, L.H., Mackin, E.J. & Callahan, A.,(Ed.), Rehabilitation of the Hand (3rd ed.) (pp.1210-1213). St Louis: C.V. Mosby Company.

Powell, D.M., Zimmer, C.A., Antoine, M.M., Baruch, L.D., Bellian, K.T., Morgan, R.F., & Edlich, R.F. (1991). Computer analysis of the performance of the BTE work simulator. Journal of Burn Care and Rehabilitation, 12, 150-256.

Rodgers, S.H. (1988). Job evaluation in worker fitness determination. Occupational Medicine, 3(2), 219-239.

Sawka, M.N. (1986). Physiology of upper body exercise. In K.B. Pandolf (Ed.). Exercise and Sport Sciences Reviews, Vol. 14 (pp. 175-211). New York: MacMillan Press.

Sharkey, B.J. (1987). Functional vs chronological age. Medicine and Science in Sports and Exercise, 19(2), 174-177.

Shephard, R.J. (1990). Assessment of occupational fitness in the context of human rights legislation. Canadian Journal of Sports Sciences, 15(2), 89-95.

Shephard, R.J. (1987). Human rights and the older worker: changes in work capacity with age. Medicine and Science in Sports and Exercise, 19(2), 168-173.

Skinner, J.S., Hustler, R., Bergsteinova, V., & Buskirk, E.R. (1973). The validity and reliability of a rating scale of perceived exertion. Medicine and Science in Sports and Exercise, 5(2), 94-96.

Smutock, M.A., Skrinar, G.S., & Pandolf, K.B. (1980). Exercise intensity: Subjectivity regulation by perceived exertion. Archives of Physical Medicine and Rehabilitation, 61, 569-574.

U.S. Department of Labour, Employment and Training Administration (1981). Selected Characteristics of Occupations Defined in the Dictionary of Occupational Titles. Washington, D.C.: U.S. Government Printing Office.

Weir, J.B. (1949). New methods for calculating metabolic rate with special reference to protein metabolism. Journal of Physiology, 109, 1-9.

Wilke, N.A., Sheldahl, L.M., Dougherty, S.M., Levandoski, S.G., & Tristani, F.E. (1993). Baltimore Therapeutic Equipment Work Simulator: Energy expenditure of work activities in cardiac patients. Archives of Physical Medicine and Rehabilitation, 74, 419-424.

Table 1: Characteristics of Subjects (Means and SD's)

VARIABLES	MALES (n=20)	FEMALES (n=20)
AGE, yr	24.8 (5.4)	23.7 (5.0)
HEIGHT, cm '	174.4 (7.7)	163.9 (5.7)
WEIGHT, kg '	75.8 (11.2)	59.0 (7.2)
BMI '	24.8 (2.4)	22.0 (2.3)
% BODY FAT '	11.9 (3.7)	19.6 (4.6)
LBM '	66.6 (8.7)	47.4 (5.5)

SD in parentheses
BMI - Body Mass Index - calculated as $wt(kg)/ht^2(m)$
LBM - Lean Body Mass
' - significant difference between males and females

Table 2: Peak Physiological Responses During Arm Cranking in Males and Females

VARIABLES	PEAK RESPONSES	
	MALES	FEMALES
VO_2 ' L/min	2.38 (0.42)	1.65 (0.24)
VO_2 ' ml/kg/min	31.6 (4.7)	28.0 (3.1)
HR ' bpm	184 (8.4)	175 (12.8)
V_E ' L/min	108.7 (31.5)	79.1 (17.6)
O_2 pulse	13.0 (2.4)	13.3 (16.8)
RER	1.26 (0.07)	1.31 (0.09)
V_E/VO_2	45.6 (7.0)	47.8 (7.0)

SD in parentheses
VO_2 - maximum oxygen consumption
V_E - minute ventilation
O_2 pulse - Oxygen uptake per heartbeat
RER - respiratory exchange ratio
V_E/VO_2 - ventilatory equivalent
' - significant difference between males and females

Table: 3 Comparisons of Simulated Work Performance of Three Tasks In Males and Females

VARIABLES*	SEX	WHEEL-TURN	PUSH-PULL	OVERHEAD-REACH
TORQUE ▪ in-lbs	MALES	74.0 (28.5)	133.5 (47.9)	224.9 ' (62.6)
	FEMALES	57.6 (20.9)	97.3 (39.4)	168.6 (44.9)
WORK ▪ in-lb-deg	MALES	3925 ' (1259)	4259 ' (1349)	5785 ' (1525)
	FEMALES	3013 ' (815)	2904 ' (1131)	4311 (1048)
POWER OUTPUT W	MALES	31.6 ' (9.8)	34.5 ▪' (11.4)	46.1 ' (12.1)
	FEMALES	23.5 ' (7.2)	23.2 ' (9.6)	34.6 (9.1)
POWER OUTPUT W/kg	MALES	0.43 ' (0.15)	0.47 ' (0.18)	0.62 (0.18)
	FEMALES	0.38 ' (0.16)	0.39 ' (0.16)	0.59 (0.15)

SD in parentheses
* - on the BTE all tasks are performed and measured in rotational basis.
▪ - work performed in 4 minutes is divided by 1000 to simplify readings
▪ - significant difference between each task within gender
' - significant difference between the task and overhead-reach within the same gender
' - significantly different from females for the same tasks

Table: 4 Comparison of Steady state Physiological Responses During Three Work Simulation Tasks in Males and Females

VARIABLES	SEX	WHEEL-TURN	PUSH-PULL	OVERHEAD-REACH
VO_2 L/min	MALES	1.13' (0.27)	1.16' (0.23)	1.13 (.29)
	FEMALES	0.81 (0.26)	0.80 (0.22)	0.87 (0.22)
VO_2 ml/kg/min	MALES	15.1 (4.0)	15.5 (3.4)	15.1 (4.0)
	FEMALES	14.0 (4.6)	13.6 (3.7)	14.9 (3.9)
HR b/min	MALES	123 (17.9)	125 (22.2)	126 (23.6)
	FEMALES	124 (37.1)	118 (34.3)	133 (19.5)
V_E L/min	MALES	36.5 (9.6)	37.8 (12.1)	38.8 (11.1)
	FEMALES	27.3 (10.5)	27.7 (9.4)	31.9 (9.6)
O_2 pulse	MALES	9.3 ' (2.0)	9.5 ' (2.3)	9.1 ' (2.0)
	FEMALES	6.3 (2.0)	6.1 (1.9)	6.6 (1.6)
RER	MALES	1.03 (0.09)	1.01 (0.11)	1.12 (0.16)
	FEMALES	0.99 (0.24)	1.00 (0.07)	1.13 (0.15)
V_E/VO_2	MALES	32.9 (4.4)	32.5 (6.9)	34.8 (7.6)
	FEMALE	32.2 (8.3)	34.5 (4.3)	37.1 (8.5)
% PEAK VO_2	MALES	48.6 (12.2)	49.5 (9.8)	48.6 (12.7)
	FEMALES	50.0 (16.4)	48.7 (13.4)	53.1 (12.5)

SD in parentheses
' - significantly different from females for the same tasks

Table: 5 Comparisons of Energy Expenditure During Three Work Simulation Task in Males and Females

VARIABLES	SEX	WHEEL-TURN	PUSH-PULL	OVERHEAD-REACH
ECS kcal/min	MALES	1.80 ' (0.33)	1.78 ' (0.47)	1.87 ' (0.51)
	FEMALES	1.32 (0.35)	1.47 (0.24)	1.37 (0.29)
GEC Kcal/min	MALES	5.70 ' (1.39)	5.57 ' (1.72)	5.68 (1.47)
	FEMALES	4.05 (1.31)	4.00 (1.12)	4.37 (1.12)
NEC Kcal/min	MALES	3.89 (1.33)	3.80 ' (1.39)	3.81 (1.36)
	FEMALES	2.73 (1.14)	2.53 (1.05)	3.00 (0.92)
NEC cal/min/kg	MALES	52.63 (19.10)	52.33 (16.11)	51.19 (19.06)
	FEMALES	47.35 (19.76)	43.11 (17.86)	51.69 (16.01)
NEC cal/watt/kg	MALES	1.69 (0.41)	1.58 ' (0.42)	1.09 ' ' (0.29)
	FEMALES	2.03 (0.62)	1.92 (0.44)	1.51 ' (0.33)
METS	MALES	4.36 (1.45)	4.42 (1.00)	4.29 (1.70)
	FEMALES	3.99 (1.30)	3.88 (1.06)	4.21 (1.14)

SD in parentheses
ECS - energy cost of standing (baseline)
GEC - gross energy cost
NEC - net energy cost
' - significantly different from females for the same tasks
' - significant difference between overhead-reach and other two tasks within the same gender

CHAPTER III

RELATIONSHIP OF PEAK AEROBIC AND ANAEROBIC PERFORMANCE TO HIGH INTENSITY UPPER BODY WORK SIMULATION TASKS

INTRODUCTION

Currently, a number of physical work capacity tests are used to screen individuals seeking employment requiring extensive physical work. These tests include measurement of the maximal aerobic power, muscle strength and endurance, flexibility and body composition (Davis & Dotson, 1986; Davis, Dotson & Santa Maria, 1982; Dicarlo, Supp and Taylor, 1983; Knapik, Burse & Vogel, 1983; Knapik, Wright, Kowal & Vogel, 1980; Loeppky & Luft, 1989; Patton, Daniels & Vogel, 1980; Sharp, Harman, Vogel, Knapik & Legg, 1988; Shephard, 1990; Shephard, 1987). While each of these tests provide specific information on the individual's physiological capabilities, none of them provides information pertaining to the individual's capacity to do high intensity work. Knowledge in this area is particularly important in a general assessment or a specific job related evaluation, as many occupations require short duration, high intensity efforts (CCDO, 1986). **High intensity effort** for the purpose of this study may be related to "heavy work load" which is defined as a task that is at an intensity which the person would be unable to continue for a period greater than six minutes without a rest break (Astrand & Rodahl, 1986).

Occupational therapists are well suited to play an important role in vocational evaluation. In addition to interpreting the above mentioned physical capacity tests, occupational therapy philosophy requires use of work related activities along with emphasizing an understanding of the importance of work to the individual (Lloyd & Fiqir, 1990). Work simulators are often used to imitate a wide variety of work demands (Ogden-Niemeyer & Jacobs, 1989). The Baltimore Therapeutic Equipment (BTE) work simulator was developed by Engalitcheff Jr. and Curtis in 1979 and its primary purpose was for rehabilitation and evaluation of the upper extremities (Pendergraft, Cooper, & Clark, 1990). It was designed to simulate a wide variety of normal movements with its 21 attachments (Curtis & Engalitcheff, 1981, Powell et al., 1991). The tasks chosen for this study included 1) wheel turn (WT), 2) push-pull (PP), and 3) overhead-reach (OR). These are some of the activities used to categorize jobs according to the Dictionary of Occupational Titles (DOT) and the Canadian Classification and Dictionary of Occupations Guide (CCDO). The primary advantage of using the BTE as compared to actual work tasks is that it allows for measurement of objective data. These include resistance, distance, time, work done and power output. Such objective measurements would otherwise be difficult to obtain except through indirect methods such as heart rate and oxygen consumption.(Kennedy & Bhambhani, 1991).

Physiology of High Intensity Upper Body Work:

In the past, numerous work capacity assessments for lower body exercise were done and the results used to predict upper body capacity (Sawka, 1986). Through a review of research which compared both, physiological and biomechanical responses, Sawka summarized that peak power output, heart rate, and oxygen uptake are all lower for arm crank exercise as compared to leg exercise (1986). In addition, he also found anaerobic power and capacity to be lower for arm work. Most manual material handling tasks require the use of the upper extremities (Armstrong & Silverstein, 1987; Chaffin & Anderson, 1984). It has been suggested that for the most relevant results, testing should involve the specific muscle groups involved in the activity (Bouchard, Taylor, Simoneau, & Dulac, 1991; Sawka, 1986; Rodgers, 1988).

Relationship of Peak Oxygen Uptake to Performance:

Peak VO_2 has been shown to be significantly related to endurance performance during strenuous exercise (Astrand & Rodahl, 1986; McArdle, Katch, & Katch, 1991). Sharp, Harman, Vogel, Knapik, & Legg, (1988) compared a repetitive lifting exercise which incorporated lifting a object to peak VO_2 during treadmill, leg cycling and arm cranking. All three were found to be significantly related to the repeated lifting task. Correlations for the treadmill, cycling and

arm cranking tests were 0.91, 0.83 and 0.73 respectively. They concluded that peak VO_2 was highly related to the repetitive lifting task. While peak VO_2 may be related to lifting performance, research pertaining to its relationship with other tasks in the occupational setting is lacking.

Wingate Power Test:

The Wingate Power Test is a supramaximal thirty second test which assesses anaerobic performance and is designed to quantify the amount of power that can be generated during exercise on an arm or leg cycle ergometer (Bar-Or, 1987; Patton, Murphy & Frederich, 1985; Watson & Sargeant, 1986). Several studies have indicated that the Wingate test is a valid indicator of performance in short duration athletic events that demand high intensity effort (Bar-Or 1987; Montgomery, 1988), and more specifically for upper body high intensity effort (Vandewalle, Peres, Stouvenel, & Monod, 1989). No studies have specifically focused on using the Wingate Power Test as a predictor of upper body work capacity in the occupational setting to assess work capacity. The only study found to address some aspects of work capacity testing using the Wingate Power Test was conducted by Nebelsick-Gullett, Housh, Johnson & Bauge, (1988). The purpose of this study was to compare anaerobic capacity to anaerobic work capacity. Anaerobic capacity was determined using the traditional 30 second Wingate Power

Test, while anaerobic work capacity was obtained by having subjects perform lower body cycle work tasks to exhaustion. Study results demonstrated that anaerobic capacity and anaerobic work capacity were significantly related (r=.74). However, the researchers reported that a limitation of the study was the question of the validity of Wingate Power Test to fully define the subjects' anaerobic capacity.

Rating of Perceived Exertion:

The use of the rating of perceived exertion (RPE) scale developed by Gunnar Borg in 1970 (Pandolf, 1983) is expanding in clinical settings, and may have important applications in the occupational setting (Noble, 1982). The RPE may be used relative to metabolic demands at higher workloads and could be used to set intensity of effort during vigorous effort (Dunbar et al., 1992; Eston, Davis & Williams, 1987). Ceci & Hassmen (1991) & Smutock (1980) also found that during high intensity self regulated exercise (RPE of 11 or higher), physiological measures were highly reliable. In terms of anaerobic performance, a relationship has been established between anaerobic threshold and the rating scale where subjects were found to perceive an exercise intensity equal to the anaerobic threshold as 13 (somewhat hard) (Purvis & Cureton, 1981). In addition, Patton, Morgan and Vogel, (1977) found in a study examining high intensity, absolute physical exertion

that "perception of the intensity of absolute work does not differ in groups differing in their level of fitness when studied cross-sectionally." (pg. 107). These results suggest that the Borg scale can be used as a measure of exertion in determining a consistent high intensity work level for the study.

The purpose of this study was to examine the relationship between standardized tests of aerobic and anaerobic fitness and three high intensity tasks on a work simulator in males and females.

METHODS

Subjects:

The subjects consisted of twenty healthy males and 20 healthy females who were primarily graduate and undergraduate students. The subjects volunteered their informed consent (Appendix A1) to participate in this study which had been approved by an ethics committee. As the goal of the study was to apply the data to the vocational field, subjects ages were limited to 18 years and over as this is usually the start of full time employment.

Study Protocol:

Each subject was required to complete six testing sessions. These included a familiarization session, a peak VO_2 test, a Wingate Power Test and three different work simulation

sessions.

Session 1:

A) Task Familiarization:

Subjects were asked to fill out a Physical Activity Readiness Questionnaire (PAR-Q) form (B.C. Ministry of Health 1978, Appendix A2) and a consent form. They were then asked to randomly select the order of performing the three work simulation tasks on the BTE. The work tasks chosen for the study included: **tool #131**, which simulates opening a valve and turning a steering wheel (WT), **tool #171**, which simulates push-pulling an object such as a mop or heavy tools (PP) and **tool #181**, which simulates reaching above the shoulder and pulling downward on a crossbar (OR) (BTE Manual 1986). These three tasks were selected as they are included in the U.S. Department of Labour's Dictionary of Occupational Titles (DOT) list of 20 physical demands of work (1981). They are also used to categorize jobs tasks by Canadian Classification and Dictionary of Occupations (CCDO)(1986).

The positions for the three tasks were standardized as follows. For the **WT**, the height of the shaft was adjusted so that the lower end of the wheel was at the level of the subjects umbilicus. The angle of the wheel was set at one setting towards the person from the vertical position (i.e. approximately 45 degrees). Subjects were advised to keep

their trunk as stationary as possible and to place their feet side by side a comfortable distance apart. They were then asked to rotate the wheel towards their dominant arm at a constant self selected rate using only their arms.

The height for the **PP**, was adjusted so that the shaft at the level of the elbow crease. The angle of the shaft was set parallel to the ground. The subject's dominant hand was positioned at the back end of the device with the non-dominant hand at a self-chosen comfortable position. Subjects were asked to place the foot that is contralateral to their dominant hand in the forward position while the other foot was placed a comfortable distance behind. Subjects were advised not to "sway" their entire body while pushing or pulling and to avoid trunk rotation. They were then asked to push-pull the attachment at a constant self selected rate.

For the **OR** the height of the shaft was adjusted to the level of the axillary crease. The angle of the shaft was set parallel to the ground. Subjects were asked to place their feet a comfortable distance apart. They were also told to avoid trunk use and to ensure both arms go through full range of motion. They were then asked to pull down on the attachment at a constant self selected pace. (NOTE: all tasks were demonstrated to the subjects during the familiarization session).

Once the order was determined, the BTE was set to the

position as specified by the standardized protocol. Subjects were asked to work at a self selected rate for four minutes during which time the resistance was gradually increased. The subjects were then asked to select a work intensity corresponding to a RPE of 15 (hard) on the Borg Scale (Noble, 1982) while performing the task. Even after the individual had attained a level of 15, the resistance was increased and decreased several times to ensure that a consistent rating was attained. (Note: subjects were not able to see resistance levels on the BTE.) Once the resistance was identified, the subject continued to work at that level to complete the four minutes. Subjects were given a four minute rest period between each task.

B) Measurement of Body Fat:

Body fat was estimated from total body water measurements using electrical impedance technique (RJL Systems BIA - 101 Body Composition Analyzer). This procedure has been shown to be a reliable and valid in determining percent body fat. Jackson, Pollock, Graves, & Mahar, (1988) compared bioelectrical impedance to skinfold fat and hydrostatic weighing methods and they were all found to be reliable where correlations ranged from 0.96 to 0.98. Subjects were tested following manufacturers guidelines.

Session 2 Determination of Peak Oxygen Uptake:

During this session, the subject's peak VO_2 was assessed on an arm crank ergometer (Monark 881). The test protocol as described by Bhambhani, Gomes, and Erikson, (1991) was initiated with zero resistance at a cadence of 50 rpm, and the resistance was increased every two minutes by 0.5 kgs until volitional fatigue. During the entire test, physiological measurements were monitored using an automated metabolic cart (Sensormedic's, Model MMC Horizon, California) that was calibrated following the manufacturer's specifications using standardized gases. Heart rate was recorded using an electrocardiogram (Hewlett Packard, Model 1500B, Washington) which was interfaced with the MMC.

Session 3 Wingate Power Test:

The subjects' anaerobic power and capacity were assessed using the Wingate Power Test (Bar-Or, 1987; Patton, Murphy & Frederich, 1985; Watson & Sargeant, 1986). Test protocol of the Wingate Power Test followed the traditional 30 second method using a Monark Rehab. 881 Arm Ergometer. The subjects were positioned in a comfortable sitting position with elbows slightly flexed so that the ergometer pedals were at shoulder level. The resistance (load factor) for the arm test was set at 50 g/kg for males and 45 g/kg for females (Dotan & Bar-Or, 1983).

Computerized measurements of anaerobic power were obtained using a modified arm ergometer described by Bhambhani, Kuwajima, Fleming, Rodgers, Gomes, & Wenger (1991). The modifications include the application of a sensing element where one side of the wheel has been painted black and eight self adhesive silver reflective tape has been applied equal distance apart. A photoelectric transducer will be used to read the number of rotations. The ergometer will be connected to a computer using a customized program where the following results will be calculated every .5 seconds: revolutions per minute, power output in Watts, Watts.kg-1, and Watts.kg-1 of lean body mass and work done in kilojoules (Bhambhani, et al., 1991).

The entire test lasted one minute. During the first 30 seconds (warm-up phase), the subjects pedalled at a comfortable pace. At the sound of an audio signal after 28 seconds, the subjects accelerated so that at the 30 second point they were at maximum velocity. Also at this point, a visual signal was provided to the test administrator who then released the load. The researcher strongly "urged" the subjects to give an all-out effort for the final 30 seconds of the test during which time actual measurements were taken. The peak and average power output was automatically calculated by the computer.

Sessions 4 - 6 Performance on the Work Simulator:

The following three sessions were randomly determined by the subjects who were asked to pick lots. The BTE was used in the automatic mode and was set at the resistance level corresponding to an RPE of 15 determined by the subjects during the familiarization session.

All physiological measurements, were monitored using the MMC and electrocardiogram. The subjects were asked to stand in place for three minutes so that a baseline measurement of oxygen consumption and HR could be obtained. After the three minutes, the subjects worked on the BTE (as described) for four minutes to achieve a physiological steady state.

Statistical Analysis

Gender comparisons of anthropometric and peak aerobic and anaerobic performance were completed using t-tests. Biomechanical performance on the three tasks were compared using a two-factor (2x3) ANOVA with repeated measures design where factor A had two levels (male and female) and factor B had three levels (the three different work simulation tasks). Summary tables for ANOVA's are presented in appendix C. Scheffe multiple comparisons were performed on an 'a priori' basis to compare the responses between males and females for each of the tasks. As multiple comparison were made for each for each biomechanical variable, the

Bonferroni adjustment method (Appendix D) where the alpha level was divided by the number of comparisons, was used to control for type I error (Ottenbacher, 1991). Pearson product-moment correlations were used to examine the relationship between the biomechanical response on the BTE for the three simulated work tasks and the various indices of peak aerobic and anaerobic performance. The alpha level was set at the 0.05 level for this study.

RESULTS

Subject Characteristics:

The subject characteristics are reported in table 1. There was no significant difference between males and females for age. However, all other anthropometric variables, namely height, weight, %body fat, BMI and LBM were found to be significantly different. The males were taller, heavier and had less body fat and, greater BMI and LBM.

Peak Physiological Responses:

Peak physiological responses for the incremental arm aerobic test and the Wingate Power Test are presented in table 2. A significant difference was noted for all peak physiological variables except for VO_2 LBM. Male performance was greater for all aerobic and anaerobic variables.

Performance During Three Work Simulation Tasks:

A description and comparison of the biomechanical and physiological responses within and between gender are briefly described below, as a detailed analysis is given in the preceding paper. The descriptive statistics for torque (in-lbs), work (in-lb-deg.), and power output (watts) during the three work simulation tasks are summarized in table 3. A significant difference between each task within gender for torque (in-lbs) produced was observed. The torque produced was highest for the OR reach and lowest for the WT. For work (in-lb-degrees), and power (watts), a significant difference was found between each task and OR, and no difference was found between the WT and the PP tasks within gender for both males and females. Again, the OR produced the highest output in comparison to the other two tasks. When comparing gender differences between tasks for work performance, a significant difference was found for torque and work for the OR only. Male output was significantly greater than female output. For power (watts), male output was again found to be significantly greater then females for both the PP and OR activity.

The correlations between performance on the BTE and the anthropometric and physiological variables are presented in tables 4-6.

Wheel-Turn Task: (Table 4)

There was no significant relationship between any of the physiological variables and biomechanical performance for males. For females, significant negative relationships were observed between relative and LBM anaerobic power and capacity, and work and power on the BTE.

Push-Pull Task: (Table 5)

In males, a significant relationship was evident between relative and LBM VO_2 and biomechanical work and power output. As well, BMI was found to be inversely related to all three biomechanical variables for this task. In females, absolute VO_2 was found to be significantly related to the power output only.

Overhead-Reach Task: (Table 6)

Similar to the WT task, no significant relationships were observed between any of the physiological variables and biomechanical performance for males. A significant relationship was evident in females for the absolute, relative and LBM VO_2 and work and power output for the OR task.

DISCUSSION

This study has attempted to determine if peak aerobic and/or anaerobic performance is significantly related to

high intensity upper body work on three BTE work simulation tasks. Although some relationships were observed between biomechanical performance on the BTE and indices of aerobic and anaerobic fitness, these were observed to be task and gender specific. Due to the varied relationships, it was difficult to establish a general equation that would predict simulated work performance using indices of aerobic or anaerobic fitness.

The findings of the study have several implications for the occupational therapist involved in physical capacity testing. Overall the indices of aerobic and anaerobic fitness were not consistently related to any specific biomechanical performance for any task. Through the analysis of the results, task specific differences were evident. Each task was performed on different planes using very different motions. For females, a significant correlation was observed for the OR and aerobic fitness. This may be due to the OR task being the only one of the three tasks that was similar to the arm cranking motion. This is consistent with Rodgers' (1988) findings which indicated that the most appropriate physical capacity tests for job placement or for a person returning to a job are those that are similar to the effort required. Therefore, the occupational therapist should avoid basing any conclusions solely on the clients' aerobic or anaerobic capacity. The most appropriate course of action would be to

make the evaluation as comprehensive as possible by including as many work simulation tasks that are similar to the actual work tasks the person may be required to perform (Lecher, Roth, & Straaton, (1991).

Also, where significant correlations were noted, no similarities were found between males and females. The occupational therapist must thus be aware of these gender differences when assessing performance on all work simulation tasks as well as actual work tasks. For example, in females, WT task performance in terms of work and power output, was found to be inversely related to relative and LBM anaerobic power and capacity. The data indicate for females performing the WT task, that there is a decrease in anaerobic power and capacity (Watts/kg and LBM) as work and power output increase. The reason for this inverse relationship is unknown and will require future investigation. For the OR task, work and power were noted to be significantly related to aerobic indices. These relationships were not observed in males. For males, relative and LBM VO_2 were found to be significantly related to work and power output for the PP task only. In addition, BMI was found to be inversely related to all three biomechanical responses for the same task.

This type of data with further study may allow for better prescription of rehabilitation programs as well as assist in vocational screening. The first step in most

vocational evaluation programs would be for the occupational therapist to complete a thorough job analysis that includes a comprehensive description of the work tasks, methods and techniques, outcome and so forth (Holmes, 1985). This would allow the occupational therapist to determine what tasks are predominantly required. If, for example, the work task was to be performed by a woman and required repetitive actions which are similar to the WT task, then the rehabilitation work hardening program may have to focus on aerobic rather then anaerobic training as anaerobic fitness was shown to be negatively related to work and power. In the case of job screening, an anaerobic component may not be required in the assessment battery. In the same instance, if the task required actions which are similar to the OR task, then the rehabilitation or screening assessment should include an aerobic component.

If on the other hand, the task had to be performed by a male and required repetitive high intensity push pull activity such as shovelling or pulling a hose (firefighting), then aerobic fitness would have to be considered. In addition to this, the work evaluator may want to consider the males' BMI -where the lower the index (which has been thought to be related to adiposity) (MacDougall, Wenger, & Green 1991), the higher the expected performance.

Work evaluation for the purpose of job screening and or

rehabilitation involves a team approach (Kavanagh & Matosevic, 1988). The occupational therapist is usually not directly involved in the fitness assessment component of the physical capacity testing. However, the therapist has to interpret the physical capacity results and incorporate them with data collected through job analysis, psychological feasibility testing, work simulation and actual onsite assessments. This information is combined to determine worker appropriateness for the specific vocation whether it be for re-entry or for job placement.

The results of this study indicate that a vocational assessment based solely on aerobic or anaerobic ability would be in error. It should be noted that although significant relationships were obtained for some indices, the common variance (r^2) ranged from 18% to 35%. Therefore, a large proportion (65%-82%) of the commonality between these measures are explained by factors other then the observed relationships. This is consistent with Rhodes & Farenholtz (1992) who indicated that in most cases, aerobic and anaerobic capacity are important factors in performance of high intensity work. However, other factors such as motor performance, agility, coordination, and so forth, must also be considered. For the most valid physical capacity testing, the assessment should be specific to the employment the person is pursuing (Jamnik & Gledhill, 1992). A complete needs assessment and task analysis should be

completed and a physical capacity test should then be developed that assesses all the requirements of the job (Jamnik & Gledhill, 1992). Aerobic and anaerobic testing should only be done as a screen once a baseline is determined in terms of what is required for the job.

For the occupational therapist intending to use the results of this study in designing or implementing work evaluation programs, specific limitations must be kept in mind. The first limitation is the sample utilized. Due to recruitment methods, all subjects were very homogeneous (ie. either students at the university or associated with the university in some way). This sample population may be significantly different from the average injured blue collar worker for whom the physical capacity testing is usually intended. In addition, although the Wingate Power Test has been shown to be a valid indicator of anaerobic power (Bar-Or, 1987), there is some question of its ability to fully define a person's anaerobic capacity (Nebelsick-Gullett et al 1988). Therefore, it may be valuable to use several indicators of anaerobic performance to fully determine an individual's anaerobic capacity.

In summary, the results of this study indicate that aerobic and anaerobic fitness may not be significantly related to high intensity upper body simulated work performance. The work evaluation team which evaluates job readiness on the basis of traditional fitness parameters may

be in error. This study has demonstrated the importance of considering task specific differences as well as gender differences in simulated work performance. For the most appropriate vocational evaluation, the therapist must make it specific to the type of employment the client intends to work in.

REFERENCES

Armstrong, T. J. & Silverstein, B.A. (1987). Upper extremity pain in the workplace - role of usage in casualty. In Clinical concepts in regional musculoskeletal illness (pp. 333-354). Grune & Stratton, Inc.

Astrand, P.O., Rodahl, K. (1986). Textbook of Work Physiology - Physiological Bases of Exercise. Toronto: McGraw Hill Book Company.

Baltimore Therapeutic Equipment Company (1986). Operations manual for the Baltimore Therapeutic Equipment Work Simulator (3rd ed.). Baltimore.

Bar-or, O. (1987). The Wingate anaerobic test: An update on methodology, reliability, and validity. Sports Medicine, 4, 381-394.

Bhambhani, Y. Gomes, P., & Erikson, P. (1991). Transfer effects of endurance training with the arms and legs. Medicine and Science in Sports and Exercise, 23, 1035-1041.

Bhambhani, Y., Kuwajima, F., Fleming, A., Rodgers, E., Gomes, P. & Wenger, H. (1991). Increased sensitivity of Wingate test results using a computerized system for evaluation system. Proceedings of the Annual General Meeting of the Canadian Association of Sport Sciences, (pp. 34). Kingston, Ontario, Canada.

Bouchard, C., Taylor, A.W., Simoneau, J.A., & Dulac, S. (1991). Testing maximal anaerobic power and capacity. In J.D. MacDougall, H.A. Green (eds.) Physiological Testing of High-Performance Athletes, 2nd ed. Canadian Association of Sports Sciences.

British Columbia Ministry of Health and the Department of National Health and Welfare (1978). PAR-Q Validation Report.

Canadian Classification and Dictionary of Occupations Guide (1986). Ottawa: Canadian Government Publishing Centre.

Chaffin, D. B., & Andersen, G. (1984). Manual materials handling limits. In Occupational Biomechanics. Toronto: John Wiley & Sons.

Curtis, R.M., & Engalitcheff, J., Jr. (1981). A work simulator for rehabilitating the upper extremity - preliminary report. Journal of Hand Surgery, 6(5), 499-501.

Davis, P.O., & Dotson, C.O. (1986). Job performance testing: an alternative to age discrimination. Medicine and Science in Sports and Exercise, 19(2), 179-185.

Davis, P.O., Dotson, C.O., & Laine Santa Maria, D. (1982). Relationship between simulated fire fighting tasks and physical performance measures. Medicine and Science in Sports and Medicine, 14(1), 65-71.

DiCarlo, S.E., Supp, M.D., & Taylor, H.C. (1983). Effect of arm ergometry training on physical work capacity of individuals with spinal cord injuries. Physical Therapy, 63(7), 1104-1107.

Dotan, R., & Bar-Or, O. (1983). Load optimization for the Wingate anaerobic test. European Journal of Applied Physiology, 51, 409-417.

Dunbar, C.C., Robertson, R.J., Baun, R., Blandin, M.F., Metz, K., Burdett, R., & Goss, F.L. (1992). The validity of regulating exercise intensity by ratings of perceived exertion. Medicine and Science in Sports and Exercise, 24(1), 94-99.

Eston, R.G., Davies, B.L., & Williams, J.G. (1987). Use of perceived effort ratings to control exercise intensity in young healthy adults. European Journal of Applied Physiology, 56, 222-224.

Holmes, D. (1985). The role of the occupational therapist - work evaluator. American Journal of Occupational Therapy, 39(5), 308-313.

Jackson, A.S., Pollock, M.L., Graves, J.E., & Mahar, M.T. (1988). Reliability and validity of bioelectrical impedance in determining body composition. Journal of Applied Physiology, 64(2), 529-534.

Jamnik, V.K., & Gledhill, N. (1992). Development of fitness screening protocols for physically demanding occupations. Canadian Journal of Sport Sciences, 17(3), 222-227.

Kavanagh, T., & Matosevic, V. (1988). Assessment of work capacity in patients with ischaemic heart disease: methods and practices. European Heart Journal, 9, 67-73.

Kennedy, L.E., & Bhambhani, Y.N. (1991). The Baltimore therapeutic equipment work simulator: reliability and validity at three work intensities. Archives of Physical Medicine and Rehabilitation, 72, 511-516.

Knapik, J.J., Burse, R.L., & Vogel, J.A. (1983). Height, weight, percent body fat, and indices of adiposity for young men and women entering the U.S. army. Aviation, Space, and Environmental Medicine, March,54(3), 223-231.

Knapik, J.J., Wright, J.E., Kowal, D.M., & Vogel, J.A. (1980).The influence of U.S. army basic initial entry training on the muscular strength of men and women. Aviation, Space, and Environmental Medicine, October,51(10), 1086-1090.

Lechner, D., Roth, D., & Straaton, K. (1991). Functional capacity evaluation in work disability. Work, 1(3), 37-47.

Lloyd, C., & Fiqir, N. (1990). Vocational evaluation: the use of work samples. Australian Occupational Therapy Journal, 37(4), 185-189.

Loeppky, J.A., & Luft, U.C. (1989). Work capacity, exercise responses and body composition of professional pilots in relation to age. Aviation, Space, and Environmental Medicine, November, 1077-1084.

MacDougall, J.D., Wenger, H.A., & Green, H.J. (Eds.). (1991). Physiological Testing of the High Performance Athlete. Champaign, IL: Human Kinetics Publishers, Inc.

McArdle, W.D., Katch, F.J., & Katch, V.L. (1991). Exercise Physiology, Energy, Nutrition, and Human Performance (3rd ed.) Philadelphia: Lea & Febiger.

Montgomery, D.L. (1988). Physiology of ice hockey. Sports Medicine, 5, 99-126.

Nebelsick-Gullett, L.J., Housh, T.J., Johnson, G.O., & Bauge, S.M. (1988). A comparison between methods of measuring anaerobic work capacity. Ergonomics, 31(10), 1413-1419.

Noble, B.J. (1982). Clinical applications of perceived exertion. Medicine and Science in Sports and Exercise, 14(5), 406-411.

Ogden-Niemeyer, L., & Jacobs, K. (1989). Work Hardening: State of the Art. Thorofare, NJ: Slack Inc.

Ottenbacher, K.J. (1991). Statistical conclusion validity - multiple Inferences in rehabilitation medicine American Journal of Physical Medicine and Rehabilitation, 70(6), 317-322.

Oyster, C.K., Hanten, W.P., & Llorens, L.A. (1987). Introduction to Research: A Guide for the Health Science Professional. Philadelphia: J.B. Lippincott Co.

Pandolf, K.B. 91982). Differentiated ratings of perceived exertion during physical exercise. Medicine and Science in Sports and Exercise, 14(5), 397-405.

Pandolf, K.B. (1983). Advances in the study and applications of perceived exertion. Exercise and Sport Sciences Review, 11, 118-158.

Patton, J.F., Daniels, W.L., & Vogel, J.A. (1980). Aerobic power and body fat of men and women during army basic training. Aviation, Space, and Environmental Medicine, May,51(5) 492-496.

Patton, J.F., Murphy, M.M., & Frederick, F.A. (1985). Maximal power outputs during the Wingate anaerobic test. International Journal of Sports Medicine, 6, 82-85.

Patton, J.F., Morgan, W.P., & Vogel, J.A. (1977). Perceived exertion of absolute work during a military physical training program. European Journal of Applied Physiology, 36, 107-114.

Pendergraft, K.J., Cooper, J.K., & Clark, G.L. (1990). The BTE work simulator. In Hunter, J.M., Schneider, L.H., Mackin, E.J. & Callahan, A.,(Ed.), Rehabilitation of the Hand (3rd ed.) (pp.1210-1213). St Louis: C.V. Mosby Company.

Powell, D.M., Zimmer, C.A., Antoine, M.M., Baruch, L.D., Bellian, K.T., Morgan, R.F., & Edlich, R.F. (1991). Computer analysis of the performance of the BTE work simulator. Journal of Burn Care and Rehabilitation, 12, 150-256.

Purvis, J.W., & Cureton, K.J. (1981). Ratings of perceived exertion at the anaerobic threshold. Ergonomics, 24, 295-300.

Rhodes, E.C., & Farenholtz, D.W. (1992). Police officer's physical abilities test compared to measures of physical fitness. Canadian Journal of Sport Sciences, 17(3), 228-233.

Rodgers, S.H. (1988). Job evaluation in worker fitness determination. Occupational Medicine, 3(2), 219-239.

Sawka, M.N. (1986). Physiology of upper body exercise. In K.B. Pandolf (Ed.). Exercise and Sport Sciences Reviews, Vol. 14 (pp. 175-211). New York: MacMillan Press.

Sharp, M.A., Harman, E., Vogel, J.A., Knapik, J.J., & Legg, S.J. (1988). Maximal aerobic capacity for repetitive lifting: comparison with three standard exercise testing modes. European Journal of Applied Physiology, 57, 753-760.

Shephard, R.J. (1987). Human rights and the older worker: changes in work capacity with age. Medicine and Science in Sports and Exercise, 19(2), 168-173.

Shephard, R.J. (1990). Assessment of occupational fitness in the context of human rights legislation. Canadian Journal of Sports Sciences, 15(2), 89-95.

Vandewalle, H., Peres, G., Stouvenel, O., & Monod, H. (1989). Force-velocity relationship and maximal anaerobic power during cranking exercise in young swimmers. International Journal of Sports Medicine, 10, 439-445.

Watson, R.C., & Sargeant, T.L.C. (1986). Laboratory and on-ice test comparisons of anaerobic power of ice hockey players. Canadian Journal of Applied Sport Sciences, 218-224.

Table 1: Characteristics of Subjects (Means and SD's)

VARIABLES	MALES (n=20)	FEMALES (n=20)
AGE, yr	24.8 (5.4)	23.7 (5.0)
HEIGHT, cm'	174.4 (7.7)	163.9 (5.7)
WEIGHT, kg'	75.8 (11.2)	59.0 (7.2)
BMI'	24.8 (2.4)	22.0 (2.3)
% BODY FAT'	11.9 (3.7)	19.6 (4.6)
LBM (kg)'	66.6 (8.7)	47.4 (5.5)

SD in parentheses
BMI - Body Mass Index - calculated as wt(kg)/ht^2(m)
LBM - Lean Body Mass
' - significant difference between males and females

Table 2 : Peak Aerobic and Anaerobic Performance.
(Means and SD's)

VARIABLES†	MALES		FEMALES	
	MEAN	SD	MEAN	SD
VO_2, L/min	2.38	0.42	1.65	0.24
VO_2, ml/kg/min	31.6	4.7	28.0	3.1
VO_2, ml/kg/min LBM	35.7	4.9	34.4	3.9
Peak HR, bpm	184	8.4	175	12.8
Anaer. Pow., W	349.4	79.5	183.6	61.4
Anaer. Pow., W/kg	4.58	0.58	2.93	1.12
Anaer. Pow., W/kg LBM	5.22	0.82	3.62	1.37
Anaer. Cap., W	1516.7	315.7	762.4	246.4
Anaer. Cap., W/kg	19.88	2.03	12.18	4.60
Anaer. Cap., W/kg LBM	22.60	2.57	15.10	5.72

† - All variables were significantly higher in males than in females except the VO_2 in ml/kg/min LBM. where there was no significant difference.

Table 3: Comparisons of Simulated Work Performance of Three Tasks In Males and Females

VARIABLES*	SEX	WHEEL-TURN	PUSH-PULL	OVERHEAD-REACH
TORQUE " in-lbs	MALES	74.0 (28.5)	133.5 (47.9)	224.9 ' (62.6)
	FEMALES	57.6 (20.9)	97.3 (39.4)	168.6 (44.9)
WORK " in-lb-deg	MALES	3925 ' (1259)	4259 ' (1349)	5785 ' (1525)
	FEMALES	3013 ' (815)	2904 ' (1131)	4311 (1048)
POWER OUTPUT Watts	MALES	31.6 ' (9.8)	34.5 '' (11.4)	46.1 ' (12.1)
	FEMALES	23.5 ' (7.2)	23.2 ' (9.6)	34.6 (9.1)

SD in parentheses
* - on the BTE all tasks are performed and measured in rotational basis.
" - work performed in 4 minutes is divided by 1000 to simplify readings
" - significant difference between each task within gender
' - significant difference between the task and overhead-reach within the same gender
' - significantly different from females for the same tasks

Table 4 : Correlation Matrix for Physiological Variables and Performance on the BTE during the Wheel-Turn Task.

VARIABLES	MALES			FEMALES		
	TORQUE	WORK	POWER	TORQUE	WORK	POWER
VO_2, L/min	.13	.15	.16	.13	.16	.33
VO_2, ml/kg/min	.24	.18	.19	.16	.16	.29
VO_2, ml/kg/min LBM	.27	.23	.24	.12	.23	.34
Peak HR, bpm	-.05	-.10	-.06	-.20	-.07	-.10
Anaer.Pow.,W	-.05	.10	.07	-.02	-.32	-.20
Anaer.Pow., W/kg	.02	.19	.13	-.18	-.59'	-.54'
Anaer.Pow., W/kg LBM	-.00	.17	.11	-.21	-.59'	-.55'
Anaer.Cap., W	-.12	-.07	-.09	.12	-.16	-.09
Anaer.Cap., W/kg	-.13	-.16	-.19	-.09	-.49'	-.48'
Anaer.Cap., W/kg LBM	-.13	-.12	-.17	-.10	-.49'	-.48'
% Body Fat	-.04	.08	.03	-.12	.13	.09
BMI	-.23	-.11	-.14	.22	.18	.27
LBM	-.06	.00	.01	.05	-.04	.08

Torque - in-lbs
Work - in-lbs-degrees
Power - Watts (W)
BMI - Body Mass Index
LBM - Lean Body Mass
' - correlations significant at the .05 level

Table 5 : Correlation Matrix for Physiological Variables and Performance on the BTE during the Push-Pull Task.

VARIABLES	MALES			FEMALES		
	TORQUE	WORK	POWER	TORQUE	WORK	POWER
VO_2, L/min	-.05	.19	.20	.16	.36	.41'
VO_2, ml/kg/min	.21	.43'	.44'	.05	.30	.34
VO_2, ml/kg/min LBM	.20	.47'	.47'	-.02	.22	.25
Peak HR, bpm	.12	.20	.20	.11	-.35	-.30
Anaer.Pow., W	-.23	-.08	-.08	-.01	.23	.26
Anaer.Pow., W/kg	-.06	.13	.14	-.11	.12	.13
Anaer.Pow., W/kg LBM	-.10	.07	.08	-.13	.11	.11
Anaer.Cap., W	-.29	-.21	-.21	.13	.07	.10
Anaer.Cap., W/kg	-.20	-.12	-.12	-.00	-.02	-.02
Anaer.Cap., W/kg LBM	-.25	-.17	-.16	-.02	-.04	-.04
% Body Fat	-.18	-.13	-.12	-.13	-.16	-.17
BMI	-.49'	-.42'	-.42'	.28	.10	.15
LBM	-.26	-.21	-.20	.22	.22	.27

Torque - in-lbs
Work - in-lbs-degrees
Power - watts
BMI - Body Mass Index
LBM - Lean Body Mass
' - correlations significant at the .05 level

Table 6 : Correlation Matrix for Physiological Variables and Performance on the BTE during the Overhead-Reach Task.

VARIABLES	MALES			FEMALES		
	TORQUE	WORK	POWER	TORQUE	WORK	POWER
VO_2, L/min	.12	.06	.11	.35	.49'	.54'
VO_2, ml/kg/min	.25	.10	.15	.33	.50'	.57'
VO_2, ml/kg/min LBM	.26	.16	.20	.31	.48'	.57'
Peak HR, bpm	-.02	.11	.22	-.13	-.32	-.36
Anaer.Pow., W	-.11	.15	.13	.14	.20	.19
Anaer.Pow., W/kg	-.04	.31	.25	-.14	-.23	-.23
Anaer.Pow., W/kg LBM	-.07	.30	.24	-.15	-.24	-.23
Anaer.Cap., W	-.12	-.05	-.04	.20	.17	.14
Anaer.Cap., W/kg	-.07	-.05	-.05	-.09	-.27	-.28
Anaer.Cap., W/kg LBM	-.11	.01	-.01	-.10	-.28	-.28
% Body Fat	-.11	.14	.09	-.04	-.04	.00
BMI	-.21	-.04	-.06	.31	.27	.29
LBM	-.09	-.09	-.06	.16	.15	.14

Torque - in-lbs
Work - in-lbs-degrees
Power - watts
BMI - Body Mass Index
LBM - Lean Body Mass
' - correlations significant at the .05 level

CHAPTER IV

General Discussion

There were two primary objectives of this study. The first was to compare males and females, for the biomechanical and physiological responses during three upper extremity high intensity tasks performed on the Baltimore Therapeutic Equipment (BTE) work simulator. These tasks included 1) turning a wheel, 2) a push-pull activity 3) an overhead reach activity. The second objective was to examine the relationship between indices of aerobic and anaerobic fitness and the biomechanical responses during the three work tasks in males and females for the above three tasks at a rate of perceived exertion of 15 (hard).

This study has initiated the description and established normative data for selected upper extremity, high intensity tasks on the BTE work simulator. In addition, biomechanical and physiological performances on three work simulation tasks were compared. Significant differences between tasks were observed both within and between genders. This study also attempted to determine if aerobic and/or anaerobic performance was significantly related to high intensity upper body work on three BTE work simulation tasks. Although some significant relationships were observed between biomechanical performance on the BTE and indices of aerobic and anaerobic fitness, these were

observed to be task and gender specific. Due to the varied relationships, a general equation to predict work performance from these fitness indices was not established.

Limitations:

The results of the study have important implications and uses for occupational therapists who are involved in the design and implementation of work evaluation and rehabilitation programs. However, before these data are used, several limitations that may reduce the generalizability and applicability of the findings must be kept in mind. They are as follows:

1) The first limitation is the sample utilized. Due to recruitment methods, all subjects were of a homogeneous background, (ie. either students at the university or associated with the university in some way). Therefore, this sample population may be significantly different in terms of physical capacity, training and motivation from the average injured blue collar worker for whom the physical capacity testing are usually intended for.

2) The second limitation also has to do with the sample. The age of the subjects ranged from 18 to 39 years. Work capacity has been shown to decrease with age (Astrand & Rodahl, 1986). Therefore, the results should pertain to the age group only and should not be applied to individuals beyond this age range.

3) The study only examines three of the 20 physical work demands listed by the U.S. Department of Labour (1981). The response for the three tasks chosen for the study may be significantly different from the remaining 17. It would be difficult to generalize conclusions on work performance based solely on the three tasks selected for this study.

4) The testing for high intensity upper body work capacity requires highly motivated subjects to produce good test results (Bar-Or 1987). This sample may not have given an all out effort as no specific motivational factors were included in the study. However, the protocol calls for subjects to work at an RPE of 15 which was preselected. An unmotivated subject would still have to work at the same perceived resistance but may slow his pace which was also self selected.

5) Another limitation is the use of the BTE to simulate high intensity work. There is limited normative data and research on its validity and reliability (Kennedy & Bhambhani, 1991). There is some question regarding content validity; i.e. how well does BTE work simulation relate to actual work done in the field? Wilke, Sheldahl, Dougherty, Levardoski and Tristani (1993) found a tendency for the metabolic responses on the BTE to be lower than that of actual activities. A factor that may have lowered the energy expenditure requirements for some of the activities on the BTE compared to the actual work tasks, was thought to

be the inability of the BTE to duplicate the multiple integrated components and total body movements of actual work tasks. However, presently there are no direct practical methods for measuring work capacity while doing actual work. By limiting the generalizability of the results to the three BTE task and through the use of a standardized protocol, should minimize the problem of content validity.

6) Although the Wingate Power Test has been shown to be a valid indicator of anaerobic power (Bar-Or, 1987), there is some question pertaining to its ability to fully define a person's anaerobic capacity (Nebelsick-Gullett, Housh, Johnson, & Bauge, 1988). Therefore, it may be valuable to use several indicators of anaerobic performance to fully determine an individual's anaerobic capacity.

7) Another limitation may be the subjects' knowledge of their participation in a study. They may have worked harder or chosen a work intensity level higher then they normally would be willing to do. However, this was unlikely as demonstrated by Kennedy and Bhambhani (1991) where in using similar protocol, subjects were found to underestimate work intensity on the BTE perceived as hard as compared to actual work tasks.

8) The final limitation of this study that has not been addressed involves the subsequent effects of having the subjects connected to the MMC. This can be very

uncomfortable and may alter physiological responses. Although this problem could not have been eliminated, it may have been minimized by randomizing tasks and having the subjects go through three minutes at rest while fully connected to obtain a baseline measure. In addition, any unusual measures during testing, ie. increased heart rate or unusual change in ventilation, were monitored by the researcher who determined if the test should be terminated.

Implications for Occupational Therapy:

Given the limitations of this study, the following implications for occupational therapist are identified:

1) The peak physiological responses indicate that subjects were of normal cardiovascular fitness (Sawka, 1986; McArdle, Katch, & Katch, 1991; & Astrand & Rodahl, 1986) and may be considered to be representative of this age and gender group that may be seeking employment. Therefore, the results of this study may be used for normative purposes for only these three tasks on the BTE.

2) The findings of the study indicate that there are task specific differences both within and between gender. In addition, no consistent relationship was observed between the work simulation tasks and the indices of aerobic and anaerobic fitness. Therefore, it appears for the most valid job screening evaluation or rehabilitation program, testing should be specific to the employment the person is

pursuing (Jamnik & Gledhill 1992). A thorough needs assessment and task analysis should be completed and a physical capacity test should then be developed, which should assess all the requirements of the job (Jamnik & Gledhill, 1992). The most possible course of action would be to make the evaluation as comprehensive as possible by including as many work simulation tasks that are similar to the actual work tasks the person may be required to perform (Lechner, Roth, & Straaton, 1991).

3) As well, the results also indicate that a vocational assessment based solely on aerobic or anaerobic ability would be inappropriate. In most cases, aerobic and anaerobic capacity are important factors in performance of high intensity work (Sawka 1986), however, other factors such as motor performance, agility, coordination, etc. must also be considered (Rhodes & Farenholtz, 1992). It is recommended, however, that aerobic and anaerobic testing be done as a screening procedure to evaluate the subjects fitness profile once a baseline of job requirements have been determined.

4) With changing legislation and the erosion of traditional gender barriers (Rodgers, 1988; Shephard, 1990), it is imperative that the occupational therapist is aware of any gender differences which may affect work performance. This study suggests that for certain tasks on the BTE, females would be under increased work stress both

physiologically and perceptually to produce similar biomechanical output as males (Gangelhoff, Cordain, Tucker, & Sockler, 1988). Furthermore, where significant correlation were observed between work simulation tasks and indices of aerobic or anaerobic fitness, no similarities were observed between males and females. This indicates that gender differences during high intensity upper body work may be at a physiological level. Hence, occupational therapists who may be developing a screening protocol for a specific job or a rehabilitation program should be cognizant of these gender differences in work performance. Precaution should be taken to prevent undue stress on the worker and prevent the possibility of injury due to fatigue. The occupational therapist can do this by increasing the work capacity of the person through job specific work hardening or on the job training (Rodgers, 1988; Ogden-Niemeyer & Jacobs 1989).

5) Although this study has demonstrated task specific and gender differences, this should not lead to job screening based solely on worker categories. Instead, testing should be done on an individual basis to ensure no discrimination occurs.

6) Although not a specific objective of the study, the results indicate that the Borg scale may be a valuable tool for occupational therapists in the work evaluation field (Morton, Barnett & Hale, 1992). The subjects were asked to

work at an RPE of 15. Except for absolute VO_2 and O_2 pulse most of the physiological responses evoked by the three tasks were similar both within and between gender. The Borg scale has been shown to be a valid measure of physiological work intensity (Ceci & Hassmen, 1991; Eston et al, 1987). These results also support conclusions drawn by Nobel (1982) where he found no significant differences between male and female responses working at the same RPE except for absolute VO_2. Occupational therapists should consider the use of the Borg scale as part of their assessment or treatment procedures. The therapists can assume that at a similar RPE male and female physiological responses will also be similar. This will enable them to more accurately gauge their client's perceived work intensity and physiological stress.

REFERENCES

Astrand, P.O., Rodahl, K. (1986). Textbook of Work Physiology - Physiological Bases of Exercise. Toronto: McGraw Hill Book Company.

Bar-or, O. (1987). The Wingate anaerobic test: An update on methodology, reliability, and validity. Sports Medicine, 4, 381-394.

Ceci, R., & Hassmen, P. (1991). Self-monitored exercise at three different RPE intensities in treadmill vs field running. Medicine and Science in Sports and Exercise, 23(6), 732-738.

Eston, R.G., Davies, B.L., & Williams, J.G. (1987). Use of perceived effort ratings to control exercise intensity in young healthy adults. European Journal of Applied Physiology, 56, 222-224.

Gangelhoff, J., Cordain, L., Tucker, A., & Sockler, J. (1988). Metabolic and heart rate responses to submaximal arm lever and arm crank ergometry. Archives of Physical Medicine and Rehabilitation, 69, 101-105.

Jamnik, V.K., & Gledhill, N. (1992). Development of fitness screening protocols for physically demanding occupations. Canadian Journal of Sport Sciences, 17(3), 222-227.

Kennedy, L.E., & Bhambhani, Y.N. (1991). The Baltimore therapeutic equipment work simulator: reliability and validity at three work intensities. Archives of Physical Medicine and Rehabilitation, 72, 511-516.

Lechner, D., Roth, D., & Straaton, K. (1991). Functional capacity evaluation in work disability. Work, 1(3), 37-47.

McArdle, W.D., Katch, F.J., & Katch, V.L. (1991). Exercise Physiology, Energy, Nutrition and Human Performance (3rd ed.) Philadelphia: Lea & Febiger.

Nebelsick-Gullett, L.J., Housh, T.J., Johnson, G.O., & Bauge, S.M. (1988). A comparison between methods of measuring anaerobic work capacity. Ergonomics, 31(10), 1413-1419.

Niemeyer, L., Matheson, L.N., & Carlton, R.S. (1989). Testing consistency of effort: BTE Work Simulator. Industrial Rehabilitation Quarterly, 2, 5-32.

Morton, G.G., Barnett, D.W., & Hale, L.S. (1992). A comparison of performance measures of an added-purpose task versus a single purpose task for upper extremities. American Journal of Occupational Therapy, 36, 128-133.

Noble, B.J. (1982). Clinical applications of perceived exertion. Medicine and Science in Sports and Exercise, 14(5), 406-411.

Ogden-Niemeyer, L., & Jacobs, K. (1988). Work hardening: State of the Art. Slack Incorporated: Thorofare, NJ.

Rodgers, S.H. (1988). Job evaluation in worker fitness determination. Occupational Medicine, 3(2), 219-239.

Rhodes, E.C., & Farenholtz, D.W. (1992). Police officer's physical abilities test compared to measures of physical fitness. Canadian Journal of Sport Sciences, 17(3), 228-233.

Sawka, M.N. (1986). Physiology of upper body exercise. In K.B. Pandolf (Ed.). Exercise and Sport Sciences Reviews, Vol. 14 (pp. 175-211). New York: MacMillan Press.

Shephard, R.J. (1990). Assessment of occupational fitness in the context of human rights legislation. Canadian Journal of Sports Sciences, 15(2), 89-95.

U.S. Department of Labour, Employment and Training Administration (1981). Selected Characteristics of Occupations Defined in the Dictionary of Occupational Titles. Washington, D.C.: U.S. Government Printing Office.

Wilke, N.A., Sheldahl, L.M., Dougherty, S.M., Levandoski, S.G., & Tristani, F.E. (1993). Baltimore Therapeutic Equipment Work Simulator: Energy expenditure of work activities in cardiac patients. Archives of Physical Medicine and Rehabilitation, 74, 419-424.

APPENDIX A1
Consent Form

I, _____, hereby agree to volunteer in a study entitled: **'Work Simulation: Gender Comparisons and Physiological Relationships in Healthy Subjects'**, which is being conducted by Dr. Y. Bhambhani and S. Esmail at the University of Alberta.

It is my understanding that I will be required to complete the following three tests during a three week period:

(1) a 10 to 15 minute graded exercise test on an arm ergometer, so as to determine my peak exercise capacity, and

(2) a 30 second arm cycling test which will require a maximal effort for the entire duration of the test,

(3) a 20 minute familiarization test on a work simulator during which I will be required to work with three attachments at an intensity that I subjectively feel as 'hard' to accomplish,

(4) three 10 minute sessions on the work simulator, one for each of the attachments utilized during the familiarization session, to determine the power output and energy expenditure of these tasks.

All the technical terms used in this consent form have been explained to me, and the testing procedure that I will be undertaking have been described to me so that I understand what these requirements are. It has also been made clear to me that with any type of exercise testing, there are potential risks involved, and if at any time during my participation I experience unusual discomfort, I will be allowed to terminate the test an opt out of the study should I so desire. My participation is on the condition that all the information collected will be kept confidential, and if published will be done so in a manner which does not reveal my identity.

By signing this consent form, I indicate my willingness to participate in the study and fulfil its requirements to the best of my ability.

Name:_____

Date:_____

Witness:_____

Date:_____

For further information, contact:

Dr. Y. Bhambhani, Associate Professor
Room 106, Rehabilitation Medicine Complex
Department of Occupational Therapy
University of Alberta
Edmonton, Alberta, T6G 2G4
Tel: (403) 492-7248 (office)
(403) 435-2935 (home)

S. Esmail, Bsc.OT
Tel: (403) 492-0397 (office)
(403) 438-9476 (home)

APPENDIX A2

PAR-Q FORM

Physical Activity Readiness Questionnaire (PAR-Q)*

PARTICIPANT IDENTIFICATION

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (√) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

* Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE). Translation, reproduction and use in its entirety is encouraged. Modifications by written permission only. Not to be used for commercial advertising in order to solicit business from the public.

Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

APPENDIX B
BORG SCALE

RATING OF PERCEIVED EXERTION (RPE)

The 15-point Rating of Perceived Exertion Scale is a means of measuring the individual's subjectively perceived level of physical exertion. It consists of numbers from 6 to 20 with accompanying verbal descriptions as indicated below. This simple appearing ordinal scale was developed on the basis of research on the bicycle ergometer. With median age groups, it was found to have a linear relationship to intensity of exercise (oxygen consumption) and to heart rate; that is, the heart rate at a given exercise intensity roughly corresponds to 10 times the RPE (Borg, G.A, 1982. Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, 14 (5): 377-81.)

RATING OF PERCEIVED EXERTION SCALE (RPE)

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

APPENDIX C

SUMMARY TABLES OF ANALYSES OF VARIANCE

Table C1 : Summary Table of Analysis of Variance For: Torque, in/lbs

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN	0.18874E7	173037.11	0.18874E7	4553.61	414.50	1.0	38.0	.485E-21
UNIV	SEX	39128.28	173037.11	39128.28	4553.61	8.59	1.0	38.0	0.00569
ERROR TERM: CASES(SEX)									
UNIV	TASK	345856.80	50531.06	172928.40	673.75	256.67	2.0	75.0	.284E-33
GREENHOUSE-GEISER ADJ:		EPSILON:	0.92	172928.40	673.75	256.67	1.8	68.9	.112E-30
UNIV	SEX*TASK	7869.69	50531.06	3934.84	673.75	5.84	2.0	75.0	0.00439
GREENHOUSE-GEISER ADJ:		EPSILON:	0.92	3934.84	673.75	5.84	1.8	68.9	0.00565
UNIV	CASES(SEX)	*173037.11	50531.06	4553.61	673.75	6.76	38.0	75.0	.121E-11
UNIV	TASK*CASES(SEX)	* 50531.06	****	673.75	****	****	75.0	****	****
ERROR TERM: TASK*CASES(SEX)									

Table C2 : Summary Table of Analysis of Variance For: Work, in/lb/deg

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN	0.1934E16	0.1342E15	0.1934E16	0.3532E13	547.64	1.0	38.0	.357E-23
UNIV	SEX	0.4625E14	0.1342E15	0.4625E14	0.3532E13	13.09	1.0	38.0	0.00086
ERROR TERM: CASES(SEX)									
UNIV	TASK	0.6177E14	0.4147E14	0.3088E14	0.5530E12	55.84	2.0	75.0	.140E-14
GREENHOUSE-GEISER ADJ:		EPSILON:	0.99	0.3088E14	0.5530E12	55.84	2.0	73.9	.221E-14
UNIV	SEX*TASK	0.1730E13	0.4147E14	0.8654E12	0.5530E12	1.56	2.0	75.0	0.21586
GREENHOUSE-GEISER ADJ:		EPSILON:	0.99	0.8654E12	0.5530E12	1.56	2.0	73.9	0.21620
UNIV	CASES(SEX)	*0.1342E15	0.4147E14	0.3532E13	0.5530E12	6.39	38.0	75.0	.492E-11
UNIV	TASK*CASES(SEX)	*0.4147E14	****	0.5530E12	****	****	75.0	****	****
ERROR TERM: TASK*CASES(SEX)									

Table C3 : Summary Table of Analysis of Variance For: Power, Watts

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN	123699.92	9243.65	123699.92	243.25	508.52	1.0	38.0	.133E-22
UNIV	GENDER	3152.49	9243.65	3152.49	243.25	12.96	1.0	38.0	0.00091
ERROR TERM: CASES(GENDER)									
UNIV	TASK	3979.83	2766.11	1989.91	36.88	53.95	2.0	75.0	.302E-14
GREENHOUSE-GEISER ADJ:		EPSILON:	0.90	1989.91	36.88	53.95	2.0	74.1	.441E-14
UNIV	GENDER*TASK	69.71	2766.11	34.85	36.88	0.94	2.0	75.0	0.39326
GREENHOUSE-GEISER ADJ:		EPSILON:	0.99	34.85	36.88	0.94	2.0	74.1	0.39232
UNIV	CASES(GENDER)	* 9243.65	2766.11	243.25	36.88	6.60	38.0	75.0	.223E-11
UNIV	TASK*CASES(GENDER)	* 2766.11	****	36.88	****	****	75.0	****	****
ERROR TERM: TASK*CASES(GENDER)									

Table C4 : Summary Table of Analysis of Variance For: Power, Watts/Kg

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN	27.69	2.43	27.69	0.06	433.21	1.0	38.0	.2248-21
UNIV	GENDER	0.06	2.43	0.06	0.06	0.93	1.0	38.0	0.34068
ERROR TERM: CASES(GENDER)									
UNIV	TASK	0.95	0.78	0.48	0.01	46.25	2.0	76.0	.722E-13
GREENHOUSE-GEISER ADJ:	EPSILON:	0.85		0.48	0.01	46.25	1.8	67.7	.133E-11
UNIV	GENDER*TASK	.0.01	0.78	0.58346-2	0.01	0.56	2.0	76.0	0.57335
GREENHOUSE-GEISER ADJ:	EPSILON:	0.88	0.78	0.58346-2	0.01	0.56	1.8	67.7	0.55389
UNIV	CASES(GENDER)	2.43	0.78	0.06	0.01	5.14	38.0	76.0	.107E-10
UNIV	TASK*CASES(GENDER)	0.78	****	0.01	****	****	76.0	****	****
ERROR TERM: TASK*CASES(GENDER)									

Table C5 : Summary Table of Analysis of Variance For: Oxygen uptake, L/min

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN	'0.11575E9	0.53644E7	0.11575E9	141180.40	819.90	1.0	38.0	.250E-21
UNIV	GENDER	0.30391E7	0.53644E7	0.30391E7	141180.40	21.53	1.0	38.0	0.00004
ERROR TERM: CASES(GENDER)									
UNIV	TASK	16441.59	0.21688E7	8220.79	28537.66	0.29	2.0	76.0	0.75053
GREENHOUSE-GEISER ADJ:	EPSILON:	0.88		8220.79	28537.66	0.29	1.8	67.1	0.72336
UNIV	GENDER*TASK	55393.65	0.21688E7	27696.83	28537.66	0.97	2.0	76.0	0.38383
GREENHOUSE-GEISER ADJ:	EPSILON:	0.88		27696.83	28537.66	0.97	1.8	67.1	0.37492
UNIV	CASES(GENDER)	*0.53644E7	0.21688E7	141180.40	28537.66	4.95	38.0	76.0	.152E-8
UNIV	TASK*CASES(GENDER)	*0.21688E7		28537.66	****	****	76.0	****	****
ERROR TERM: TASK*CASES(GENDER)									

Table C6 : Summary Table of Analysis of Variance For: Oxygen uptake, ml/kg/min

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN	25915.04	1376.40	25915.04	36.27	714.63	1.0	38.0	.304E-25
UNIV	GENDER	36.75	1376.40	36.75	36.27	1.01	1.0	38.0	0.32055
ERROR TERM: CASES(GENDER)									
UNIV	TASK	5.29	476.72	2.65	6.30	0.42	2.0	76.0	0.65857
GREENHOUSE-GEISER ADJ:	EPSILON:	0.87		2.65	6.30	0.42	1.7	66.1	0.63063
UNIV	GENDER*TASK	15.01	476.72	7.51	6.30	1.19	2.0	76.0	0.30936
GREENHOUSE-GEISER ADJ:	EPSILON:	0.87		7.51	6.30	1.19	1.7	66.1	0.30539
UNIV	CASES(GENDER)	* 1376.40	476.72	36.27	6.30	5.76	38.0	76.0	.498E-10
UNIV	TASK*CASES(GENDER)	* 476.72	****	6.30	****	****	76.0	****	****
ERROR TERM: TASK*CASES(GENDER)									

Table C7 : Summary Table of Analysis of Variance For:
Heart Rate, b/min

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		0.18731E7	50045.51	0.18731E7	1316.99	1422.28	1.0	38.0	.101E-30
UNIV	GENDER		1.10	50045.51	1.10	1316.99	0.8368E-3	1.0	38.0	0.97707
ERROR	TERM: CASES(GENDER)									
UNIV	TASK		1510.29	35983.67	755.14	473.60	1.59	2.0	76.0	0.20873
	GREENHOUSE-GEISER ADJ:		EPSILON:		0.79	755.14	473.60	1.59	1.6	60.4	0.21423
UNIV	GENDER*TASK		968.70	35983.67	484.85	473.60	1.02	2.0	76.0	0.36414
	GREENHOUSE-GEISER ADJ:		EPSILON:		0.79	484.85	473.60	1.02	1.6	60.4	0.35029
UNIV	CASES(GENDER)	*	50045.51	35983.67	1316.99	473.60	2.78	38.0	76.0	0.00008
UNIV	TASK*CASES(GENDER)	*	35983.67	****	473.60	****	****	76.0	****	****
ERROR	TERM: TASK*CASES(GENDER)									

Table C8 : Summary Table of Analysis of Variance For:
Minute Ventilation, L/min

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		133316.08	9157.26	133316.08	240.98	553.22	1.0	38.0	.298E-23
UNIV	GENDER		2271.05	9157.26	2271.05	240.98	9.42	1.0	38.0	0.00394
ERROR	TERM: CASES(GENDER)									
UNIV	TASK		256.56	3859.72	128.29	50.79	2.55	2.0	76.0	0.08508
	GREENHOUSE-GEISER ADJ		EPSILON:		0.82	128.29	50.79	2.55	1.6	62.1	0.09677
UNIV	GENDER*TASK		46.22	3859.72	24.11	50.79	0.47	2.0	76.0	0.62387
	GREENHOUSE-GEISER ADJ		EPSILON:		0.82	24.11	50.79	0.47	1.6	62.1	0.58582
UNIV	CASES(GENDER)	*	9157.26	3859.72	240.98	50.79	4.75	38.0	76.0	0.404E-8
UNIV	TASK*CASES(GENDER)	*	3859.72	****	50.79	****	****	76.0	****	****
ERROR	TERM: TASK*CASES(GENDER)									

Table C9 : Summary Table of Analysis of Variance For:
Oxygen pulse

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		7343.23	311.26	7343.23	8.19	896.49	1.0	38.0	.482E-27
UNIV	GENDER		210.73	311.26	210.73	8.19	25.73	1.0	38.0	0.00001
ERROR	TERM: CASES(GENDER)									
UNIV	TASK		0.52	60.53	0.26	0.82	0.32	2.0	74.0	0.72803
	GREENHOUSE-GEISER ADJ		EPSILON		0.99	0.26	0.82	0.32	2.0	73.3	0.72707
UNIV	GENDER*TASK		1.36	60.53	0.68	0.82	0.83	2.0	74.0	0.43971
	GREENHOUSE-GEISER ADJ		EPSILON:		0.99	0.68	0.82	0.83	2.0	73.3	0.43879
UNIV	CASES(GENDER)	*	311.26	60.53	8.19	0.82	10.01	38.0	74.0	.439E-15
UNIV	TASK*CASES(GENDER)	*	60.53	****	0.82	****	****	74.0	****	****
ERROR	TERM: TASK*CASES(GENDER)									

Table C10 : Summary Table of Analysis of Variance For: Respiratory Exchange Ratio

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		131.86	0.80	131.86	0.02	5580.47	1.0	38.0	.785E-62
UNIV	GENDER		0.3307E-2	0.80	0.3307E-2	0.02	0.14	1.0	38.0	0.71038
ERROR TERM: CASES(GENDER)										
UNIV	TASK		0.34	1.73	0.17	0.02	7.52	2.0	76.0	0.00106
	GREENHOUSE-GEISER ADJ:	EPSILON:	0.62		0.17	0.02	7.52	1.2	47.3	0.00943
UNIV	GENDER*TASK		0.01	1.73	0.7052E-2	0.02	0.31	2.0	76.0	0.73462
	GREENHOUSE-GEISER ADJ:	EPSILON:	0.62	0.7052E-2		0.02	0.31	1.2	47.3	0.62984
UNIV	CASES(GENDER)		0.90	1.73	0.02	0.02	1.04	38.0	76.0	0.43671
UNIV	TASK*CASES(GENDER)		1.73	****	0.02	****	****	76.0	****	****
ERROR TERM: TASK*CASES(GENDER)										

Table C11 : Summary Table of Analysis of Variance For: Ventilatory Equivalent

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		138768.88	2683.95	138768.88	70.63	1964.72	1.0	38.0	.250E-33
UNIV	GENDER		114.96	2683.95	114.96	70.63	1.63	1.0	38.0	0.20977
ERROR TERM: CASES(GENDER)										
UNIV	TASK		158.04	986.58	79.02	13.15	6.01	2.0	75.0	0.00380
	GREENHOUSE-GEISER ADJ	EPSILON	0.96		79.02	13.15	6.01	1.9	71.9	0.00434
UNIV	GENDER*TASK		11.67	986.58	5.84	13.15	0.44	2.0	75.0	0.64330
	GREENHOUSE-GEISER ADJ	EPSILON:	0.96		5.84	13.15	0.44	1.9	71.9	0.63503
UNIV	CASES(GENDER)	*	2683.95	986.58	70.63	13.15	5.37	38.0	75.0	0.301E-9
UNIV	TASK*CASES(GENDER)	*	986.58	****	13.15	****	****	75.0	****	****
ERROR TERM: TASK*CASES(GENDER)										

Table C12 : Summary Table of Analysis of Variance For: Energy Cost Standing, kcal/min

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		312.37	7.46	312.37	0.20	1590.77	1.0	38.0	127E-31
UNIV	SEX1		5.64	7.46	5.64	0.20	28.70	1.0	38.0	0.433E-5
ERROR TERM: CASES(SEX1)										
UNIV	TASK		0.09	4.34	0.04	0.06	0.76	2.0	74.0	0.47118
	GREENHOUSE-GEISER ADJ	EPSILON	0.94		0.04	0.06	0.76	1.9	69.3	0.46355
UNIV	SEX1*TASK		0.06	4.34	0.03	0.06	0.50	2.0	74.0	0.60690
	GREENHOUSE-GEISER ADJ	EPSILON:	0.94		0.03	0.06	0.50	1.9	69.3	0.59508
UNIV	CASES(SEX1)	*	7.46	4.34	0.20	0.06	3.35	38.0	74.0	0.430E-5
UNIV	TASK*CASES(SEX1)	*	4.34	****	0.06	****	****	74.0	****	****
ERROR TERM: TASK*CASES(SEX1)										

Table C13 : Summary Table of Analysis of Variance For: Gross Energy Cost, kcal/min

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		2925.07	129.74	2925.07	3.41	856.73	1.0	38.0	.112E-26
UNIV	SEX1		69.59	129.74	69.59	3.41	20.38	1.0	38.0	0.00006
ERROR TERM: CASES(SEX1)										
UNIV	TASK		0.17	45.97	0.09	0.62	0.14	2.0	74.0	0.87040
GREENHOUSE-GEISER ADJ:			EPSILON:	0.91	0.09	0.62	0.14	1.8	67.5	0.85207
UNIV	SEX1*TASK		1.70	45.97	0.85	0.62	1.37	2.0	74.0	0.26148
GREENHOUSE-GEISER ADJ:			EPSILON:	0.91	0.85	0.62	1.37	1.8	67.5	0.26132
UNIV	CASES(SEX1)	*	129.74	45.97	3.41	0.62	5.50	38.0	74.0	0.208E-9
UNIV	TASK*CASES(SEX1)	*	45.97	****	0.62	****	****	74.0	****	****
ERROR TERM: TASK*CASES(SEX1)										

Table C14 : Summary Table of Analysis of Variance For: Net Energy Cost, kcal/min

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		1326.28	111.22	1326.28	2.93	453.14	1.0	38.0	.102E-21
UNIV	SEX1		35.56	111.22	35.56	2.93	12.15	1.0	38.0	0.00125
ERROR TERM: CASES(SEX1)										
UNIV	TASK		0.44	41.93	0.22	0.57	0.39	2.0	74.0	0.67847
GREENHOUSE-GEISER ADJ:			EPSILON:	0.92	0.22	0.57	0.39	1.8	67.8	0.66061
UNIV	SEX1*TASK		2.22	41.93	1.11	0.57	1.96	2.0	74.0	0.14783
GREENHOUSE-GEISER ADJ:			EPSILON:	0.92	1.11	0.57	1.96	1.8	67.8	0.15198
UNIV	CASES(SEX1)	*	111.22	41.93	2.93	0.57	5.17	38.0	74.0	0.841E-9
UNIV	TASK*CASES(SEX1)	*	41.93	****	0.57	****	****	74.0	****	****
ERROR TERM: TASK*CASES(SEX1)										

Table C15 : Summary Table of Analysis of Variance For: Net Energy Cost, cal/min/kg

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		295582.33	28549.58	295582.33	751.30	394.76	1.0	38.0	113E-20
UNIV	GENDER		653.85	28549.58	653.85	751.30	0.87	1.0	38.0	0.35677
ERROR TERM: CASES(GENDER)										
UNIV	TASK		281.78	10517.86	140.89	138.39	1.02	2.0	76.0	0.36617
GREENHOUSE-GEISER ADJ:			EPSILON:	0.84	140.89	138.39	1.02	1.7	63.7	0.35552
UNIV	GENDER*TASK		477.44	10517.86	238.72	138.39	1.72	2.0	76.0	0.18509
GREENHOUSE-GEISER ADJ:			EPSILON:	0.84	238.72	138.39	1.72	1.7	63.7	0.19066
UNIV	CASES(GENDER)	*	28549.58	10517.86	751.30	138.39	5.43	38.0	76.0	0.199E-8
UNIV	TASK*CASES(GENDER)	*	10517.86	****	138.39	****	****	76.0	****	****
ERROR TERM: TASK*CASES(GENDER)										

Table C16 : Summary Table of Analysis of Variance For: Net Energy Cost, cal/watt/kg

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		322.67	11.15	322.67	0.29	1100.00	1.0	38.0	.118E-28
UNIV	GENDER		5.00	11.15	5.00	0.29	17.04	1.0	38.0	0.00019
ERROR TERM: CASES(GENDER)										
UNIV	TASK		7.72	3.97	3.86	0.05	72.91	2.0	75.0	.258E-17
GREENHOUSE-GEISER ADJ:		EPSILON:	0.86	3.86	0.05	72.91	1.7	64.2	.510E-15
UNIV	GENDER*TASK		0.04	3.97	0.02	0.05	0.34	2.0	75.0	0.71515
GREENHOUSE-GEISER ADJ:		EPSILON:	0.86	0.02	0.05	0.34	1.7	64.2	0.68178	
UNIV	CASES(GENDER)	*	11.15	3.97	0.29	0.05	5.54	38.0	75.0	0.1468-9
UNIV	TASK*CASES(GENDER)	*	3.97	****	0.05	****	****	75.0	****	****
ERROR TERM: TASK*CASES(GENDER)										

Table C17 : Summary Table of Analysis of Variance For: METS

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		2120.16	101.92	2120.16	2.68	790.49	1.0	38.0	486E-26
UNIV	SEX1		1.98	101.92	1.98	2.68	0.74	1.0	38.0	0.39535
ERROR TERM: CASES(SEX1)										
UNIV	TASK		0.24	32.60	0.12	0.44	0.27	2.0	74.0	0.76066
GREENHOUSE-GEISER ADJ:		EPSILON:	0.93	0.12	0.44	0.27	1.9	69.1	0.74562	
UNIV	SEX1*TASK		1.62	32.60	0.81	0.44	1.83	2.0	74.0	0.16708
GREENHOUSE-GEISER ADJ:		EPSILON:	0.93	0.81	0.44	1.83	1.9	69.1	0.16995	
UNIV	CASES(SEX1)	*	101.92	32.60	2.68	0.44	6.09	38.0	74.0	.191E-10
UNIV	TASK*CASES(SEX1)	*	32.60	****	0.44	****	****	74.0	****	****
ERROR TERM: TASK*CASES(SEX1)										

APPENDIX D

Bonferroni Adjustment

Chapter 2:

Table 3: Simulated work performance of three tasks in males and females

α = 0.05 ÷ by 4 (# of comparisons) = 0.0125 level

Table 4: Steady state physiological responses during three work simulation tasks in males and females

α = 0.05 ÷ by 8 (# of comparisons) = 0.006 level

Table 5: Energy expenditure during three work simulation tasks in males and females

α = 0.05 ÷ by 6 (# of comparisons) = 0.008 level

Note: Comparisons made in chapter 3 were similar to ones done in chapter 2.